The Information Sharing Strategy and Incentive Mechanism in a Dual-Channel Supply Chain under Trade Credit Financing

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Abstract. To investigate the information sharing strategy and incentive mechanism in a dual-channel supply chain with capital constraints, we build a Stackelberg game model of a manufacturer and a capital-constrained retailer in the presence of trade credit financing, study the optimal decisions and expected profits of the supply chain partners under demand forecast information sharing, and explore the information sharing strategy. Finally, based on Nash bargaining theory, we propose an incentive mechanism of information sharing in a dual-channel supply chain with capital constraints. The results are as follow, first, the optimal decisions of the supply chain partners are affected by demand forecast, deferred payment rate and other variables. Second, although the information sharing can improve the profits of the manufacturer and supply chain system, it will hurt the retailer and lead to the retailer not sharing demand forecast information with the manufacturer. Third, under certain conditions, compared with the case of no information sharing, the information sharing incentive mechanism can achieve a Pareto improvement for the retailer and the manufacturer, resulting in both parties agreeing on market demand information sharing.

Keywords: capital constraints; dual-channel supply chain; demand forecast; information sharing; deferred payment

1 Introduction

With the development of e-commerce and the increasing diversification of customer needs, IBM, Apple, and many other companies have opened online direct sales channels besides the traditional physical stores. However, compared with the supply chains with a single channel, the dual-channel model has more requirements for collaboration ability, service levels, and technologies, which can incur higher operation costs, such that many dual-channel companies often face a shortage of funds [1-2], which may reduce the operational efficiency of the whole supply chain. Therefore, some literature focus on the finance and operations decision of the dual-channel supply chains with capital constraints. In particular, Fan et al. [1] studied the pricing and inventory strategies for the dual-channel supply chain under deferred payment. Zhao et al. [3] analyzed

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the cash flow risks arising from deferred payment in dual-channel supply chains. Zhao et al. [2] proposed a coordination mechanism for dual-channel supply chains under prepayment financing based on revenue sharing and buyback contracts. Shi et al. [4] built a Stackelberg game model of the dual-channel manufacturer and the capital-constrained retailer and found that the expected demand of the retailer under the bank loan is greater when the risk aversion of the suppliers is higher. Zhang et al. [5] explored the financing strategy by comparing the order pricing decisions and expected profits of the dual-channel supply chain partners under different financing schemes.

Most of the above studies consider the information symmetry situation, assuming that all the supply chain partners have complete information on future market demand but ignore the impact of demand information asymmetry and information sharing strategies. Nevertheless, compared to manufacturers, retailers are closer to end-consumers and can acquire information advantages through face-to-face shopping guide services; thus, they often deeply analyze consumer preferences to obtain more private demand forecast information by utilizing TOF, big data, and other technologies. In the presence of demand information asymmetry, will the dual-channel supply chain partners with capital constraints choose to share information? How should companies design the incentive mechanism?

Based on the above discussion, we build a Stackelberg game model of a manufacturer and a capital-constrained retailer, consider trade credit financing, investigate the optimal decisions and expected profits of supply chain partners under the information and no information sharing scenarios, and explore the information sharing strategies and incentive contract.

2 The Model

We develop a dual-channel supply chain with a manufacturer and a capital-constrained retailer under trade credit financing (deferred payment). As the supply chain leader, the manufacturer produces a single product and sells the products to customers through two channels: 1) The manufacturer sells products directly to customers through the Internet e-commerce channel (online channel). 2) The manufacturer distributes products to the retailer responsible for marketing. The retailer is a follower in the supply chain and sells products to customers after purchasing from the manufacturer; meanwhile, it is capital-constrained and has to defer a portion of the payment to the manufacturer.

The retailer can forecast future market demand according to historical sales data and decide whether to share the demand information with the manufacturers based on their profits.

The notations are as follows,

p_m, p_r, w and c denote the retail price in online and offline channels, the wholesale price, and the production cost, respectively, and satisfy $c \le w$, $w(1+r) \le p_r$ and $c \le p_m$;

d_m and d_r denote the market demand in online and offline channels and satisfy $d_m = a - p_m + \beta p_r$ and $d_r = a - p_r + \beta p_m$, where a denotes the market potential, and β ($0 < \beta < 1$) represents the coefficient of cross-price elasticity [6];

A denotes the retailer's initial funds;

π_r and π_m represent the expected profits of the retailer and the manufacturers, respectively;

r ($0 \le r \le 1$) represents the interest rate of deferred payment.

According to the model of Li [7] and Nie [8], the market potential is random because of the impact of natural disasters or economic fluctuations, and hence let the market potential $a = a_0 + \varepsilon$, where a_0 is fixed and ε is a random variable that represents the market fluctuation and follows a normal distribution, the expectation $E[\varepsilon] = 0$ and the variance $Var(\varepsilon) = s$. Because retailers have closer relationship with consumers through shopping guide services and after-sales services, and acquire more marketing information, they can forecast market potential more accurately when compared to manufacturers. For tractability, let the accuracy of the demand forecast information of the manufacturer be 0, that is, the manufacturer only knows the fixed market potential a_0, whereas the retailer's market potential forecast is $f = a + e$, where e is the error term that is independent of a, its expectation is 0, and its variance is v. Consistent with Li [7], we can obtain

$$E(a|f) = (1-t)a_0 + tf$$

$$E((f - a_0)^2) = s + v$$

Similar to the model of Nie [8], we use t to denote the accuracy of market potential forecast, where $t = \frac{s}{s+v}$ and $0 < t < 1$. A larger t indicates the more accurate market potential forecast.

3 No Information sharing

When the retailer does not share demand information with the manufacturer and defers payment, the sequence of events is as follows: (1) the manufacturer determines the wholesale price w and the retail price in online channel p_m based on a_0; (2) the retailer determines the retail price in offline channel p_r based on f; (3) the retailer orders from the manufacturer and pays a portion of purchasing costs after the manufacturer completes production; (4) the retailer sells the product to the customers and receives the revenue; (5) the retailer pays the remaining purchasing costs to the manufacturer. The retailer's and the manufacturer's optimization problems are as follows,

$$\begin{aligned} \max E[\pi_r(p_r) \mid f] &= E[(p_r - w)d_r - (wd_r - A)r \mid f] \\ &= E[(p_r - w)(a - p_r + \beta p_m) - (w(a - p_r + \beta p_m) - A)r \mid f] \end{aligned} \quad (1)$$

$$\max E[\pi_m(p_m,w)] = (w-c)d_r + (p_m-c)d_m + (wd_r - A)r$$
$$= (w-c)(a_0 - p_r + \beta p_m) + (p_m - c)(a_0 - p_m + \beta p_r) + (w(a_0 - p_r + \beta p_m) - A)r \tag{2}$$

By solving the game backward, we obtain the optimal retail prices and wholesale price as follows, respectively.

$$p_r^* = \frac{c(1-\beta^2) + 2[a_0 - t(a_0 - f)](1-\beta) + a_0(1+\beta)}{4(1-\beta)}$$

$$p_m^* = \frac{a_0 + c(1-\beta)}{2(1-\beta)}$$

$$w^* = \frac{a_0 + c(1-\beta)}{2(1-\beta)(1+r)}$$

4 Information Sharing

When the retailer shares demand information with the manufacturer and defers partial payment, the sequence of events is as follows: (1) the manufacturer determines the wholesale price w and the retail price in online channel p_m based on f; (2) the retailer determines the retail price in offline channel p_r based on f; (3) the retailer orders from the manufacturer and pays a portion of purchasing costs after the manufacturer completes production; (4) the retailer sells the product to the customers and receives the revenue; (5) the retailer pays the remaining purchasing costs to the manufacturer. The retailer's and the manufacturer's optimization problems are as follows,

$$\max E[\pi_r(p_r) \mid f] = E[(p_r - w)d_r - (wd_r - A)r \mid f]$$
$$= E[(p_r - w)(a - p_r + \beta p_m) - (w(a - p_r + \beta p_m) - A)r \mid f] \tag{3}$$

$$\max E[\pi_m(p_m,w) \mid f] = E[(w-c)d_r + (p_m-c)d_m + (wd_r - A)r \mid f]$$
$$= E[(w-c)(a - p_r + \beta p_m) + (p_m - c)(a - p_m + \beta p_r) + (w(a - p_r + \beta p_m) - A)r \mid f] \tag{4}$$

By solving the game backward, we obtain the optimal retail prices and wholesale price as follows, respectively.

$$p_r^{**} = \frac{c(1-\beta^2) + (3-\beta)[(1-t)a_0 + tf]}{4(1-\beta)}$$

$$p_m^{**} = \frac{[(1-t)a_0 + tf] + c(1-\beta)}{2(1-\beta)}$$

$$w^{**} = \frac{[(1-t)a_0 + tf] + c(1-\beta)}{2(1-\beta)(1+r)}$$

5 Comparative Analysis

By comparing the expected profits of the retailer and the manufacturer under no information and information sharing scenarios, we further explore the information sharing strategy.

Theorem 1 Market potential information sharing reduces the retailer' expected profit but improve the manufacturer' expected profits.

Proof The difference in the retailer's expected profit between no information and information sharing situations is

$$\pi_r{}^* - \pi_r{}^{**} = \frac{3ts}{16} > 0$$

The difference in the manufacturer's expected profit between no information and information sharing situations is

$$\pi_m{}^* - \pi_m{}^{**} = \frac{-ts(\beta + 3)}{8(1-\beta)} < 0$$

Theorem 2 Market potential information sharing can increase the expected profit of the whole supply chain.

Proof The difference in the whole supply chain's expected profit between no information and information sharing situations is

$$\pi_s{}^* - \pi_s{}^{**} = (\pi_r{}^* + \pi_m{}^*) - (\pi_r{}^{**} + \pi_m{}^{**}) = -\frac{ts(3+5\beta)}{16(1-\beta)} < 0$$

Theorems 1 and 2 show that information sharing increases manufacturer’s and even the whole supply chain’s profits, though it hurts the retailer. This is because the manufacturer, as the leader in the supply chain, can set a more reasonable price after obtaining market potential forecast information to get more profits, whereas the retailers will lose information rents under information sharing situation, resulting in the lower profit.

6 Information Sharing Incentive Mechanism

Combining Theorem 1 and Theorem 2, it is clear that information sharing increases the expected profits of the manufacturer and the whole supply chain, but leads to the decrease in the retailer's profit. Therefore, the retailer has no incentive to share information unless it gets sufficiently high compensation. In this section, we discuss the compensation incentive to promote information sharing, in which the manufacturer can get market potential information by paying information fee to motivate the retailer to share information, resulting in the higher profits of the supply chain partners.

Based on Nash bargaining theory, we assume that the manufacturer pays the retailer a fee F to share market potential forecast information, the bargaining power of the retailer and the manufacturer are λ_r and λ_m, respectively, where $\lambda_r + \lambda_m = 1$, $\lambda_r > 0$ and $\lambda_m > 0$, and the retailer's and the manufacturer's profits are $\pi_{ry}^* = \pi_r^{**} + F$ and $\pi_{my}^* = \pi_m^{**} - F$, respectively. Both the parties share market potential information if and only if $\pi_m^{**} - F \ge \pi_m^*$ and $\pi_r^{**} + F \ge \pi_r^*$. Similar to the approach of Nagarajan et al. [9], the bargaining model for the retailer and the manufacturer is as follows,

$$\begin{aligned} &\max(\pi_{ry}^* - \pi_r^*)^{\lambda_r}(\pi_{my}^* - \pi_m^*)^{\lambda_m} \\ &s.t.\ \pi_{ry}^* - \pi_r^* \ge 0 \\ &\quad \pi_{my}^* - \pi_m^* \ge 0 \\ &\quad \pi_{ry}^* + \pi_{my}^* \le \pi_r^{**} + \pi_m^{**} \\ &\quad \lambda_r + \lambda_m = 1 \end{aligned} \tag{5}$$

By solving the above optimization problem, we can obtain $F = \lambda_r(\pi_m^{**} - \pi_m^*) - \lambda_m(\pi_r^{**} - \pi_r^*)$. The information sharing costs are affected by the bargaining powers, the accuracy of market potential forecast, and the coefficient of cross-price elasticity. Specifically, the manufacturer with higher bargaining power takes the initiative in the negotiation and can pay lower fee to share information. Moreover, when the accuracy of market potential forecast of the retailer is higher, the profits of the manufacturer and the whole supply chain is larger after information sharing, whereas the retailer's profit decreases, resulting the more information sharing costs.

Theorem 3 Under information sharing incentive, the retailer's profit $\pi_{ry}^* = \pi_r^* + \lambda_r l > \pi_r^*$, manufacturer's expected profit $\pi_{my}^* = \pi_m^* + \lambda_m l > \pi_m^*$, where $l = \pi_s^{**} - \pi_s^*$ denotes the improved profit of the whole supply chain because of information sharing.

Proof By substituting $F = \lambda_r(\pi_m^{**} - \pi_m^*) - \lambda_m(\pi_r^{**} - \pi_r^*)$ and $\lambda_r + \lambda_m = 1$ back to the profit functions, we have

$$\begin{aligned} \pi_{ry}^* &= \pi_r^{**} + F = \pi_r^{**} + \lambda_r(\pi_m^{**} - \pi_m^*) - (1-\lambda_r)(\pi_r^{**} - \pi_r^*) \\ &= \pi_r^* + \lambda_r(\pi_r^{**} - \pi_r^*) + \lambda_r(\pi_m^{**} - \pi_m^*) \\ &= \pi_r^* + \lambda_r(\pi_s^{**} - \pi_s^*) \end{aligned}$$

$$\begin{aligned} \pi_{my}^* &= \pi_m^{**} - F = \pi_m^{**} - (1-\lambda_m)(\pi_m^{**} - \pi_m^*) + \lambda_m(\pi_r^{**} - \pi_r^*) \\ &= \pi_m^* + \lambda_m(\pi_m^{**} - \pi_m^*) + \lambda_m(\pi_r^{**} - \pi_r^*) \\ &= \pi_m^* + \lambda_m(\pi_s^{**} - \pi_s^*) \end{aligned}$$

According to Theorem 3, we have $\pi_s^{**} - \pi_s^{*} = \frac{ts(3+5\beta)}{16(1-\beta)} > 0$, then $\pi_{ry}^{*} = \pi_r^{*} + \lambda_r(\pi_s^{**} - \pi_s^{*}) > 0$ and $\pi_{my}^{*} = \pi_m^{*} + \lambda_m(\pi_s^{**} - \pi_s^{*}) > 0$. That is, this incentive mechanism can achieve a Pareto improvement for the retailer and the manufacturer compared with the case without information sharing.

Theorem 3 shows that, under certain conditions, this compensation incentives can increase both the retailer's and the manufacturer's profits compared with the case without information sharing, which makes both parties agree on sharing market potential information and enhances the profit of the whole supply chain.

7 Conclusion

We consider a dual-channel supply chain with capital constraints, develop a Stackelberg game model for the manufacturer and the capital-constrained retailer under trade credit financing, studies the optimal decisions and expected profits of the supply chain partners under no information or information sharing, and explore the information sharing strategy. Moreover, based on Nash bargaining theory, we propose an incentive mechanism for information sharing in a dual-channel supply chain with capital constraints. The main results can be summarized as follows.

(1) We propose the optimal wholesale price and retail prices in online and offline channel for a dual-channel supply chain with capital constraints in the case with or without information sharing.

(2) We propose an incentive mechanism and confirm the optimal information sharing costs. Under certain conditions, this compensation incentive mechanism can achieve a Pareto improvement of the retailer's and the manufacturer's revenues compared with the no information sharing situation, implying that both parties agree on sharing the market potential information.

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