Ordering Strategy for Fresh Agricultural Products in External Financing Condition

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Abstract This paper firstly introduced the two stage supply chain consisting of single agricultural product producer and fund restraint retailer. Then, it analyzed the influence of bank interest rate on order quantity, wholesale price and expected profit of retailer and producer on the condition of retailer taking external loan strategy. Studies have shown that when the bank interest rate is in (0, 0.9), the order quantity of agricultural products is a decreasing function of bank interest rate; when the bank interest rate is in (0, 1), wholesale price of agricultural products decreases with increase in the bank interest rate; when the bank interest rate is in (0, 0.6), the expected profit of retailer is a decreasing function of bank interest rate; when the bank interest rate is in (0, 1), the expected profit of producer decreases with increase in the bank interest rate. Finally, through simulation calculation examples, it verified suitability of the conclusion, in the hope of providing reference and application value for management of supply chain.

Key words Fund restraint, External financing, Fresh agricultural products, Ordering strategy

1 Introduction

With rapid development of economic globalization, competition of enterprises becomes more and more intense. As a result, purchase of raw materials, production, transportation, and sales will get faster and faster. In this process, it will inevitably lead to many conflicts between upstream and downstream enterprises, and an outstanding conflict is fund. For large influential leading enterprises, fund is not a problem. Nevertheless, there are numerous small and medium-sized enterprises. Different from large enterprises, they have small size, their raw material purchase, product production, transportation and sales are uncertain, and there is problem of fund shortage. In 1998, Sullivan surveyed bankrupt small and medium sized enterprises and found that 28% went bankrupt because of lack of fund1. Archibald et al. surveyed new rising high technology enterprises and found that if they fail to obtain loan for necessary fund, they will have difficulty of survival and even be faced with bankrupt2. At present, both domestic and foreign scholars have undertaken some studies on order in supply chain under the fund restraint. Mark et al. considered the order model of price dependent on inventory in random time3. Abad studied optimum order batch and price of perishable commodities in limited production condition4. Cashon et al. discussed ordering strategies of retailers in contracts of supply chain and found that the supply chain system in repurchase condition3. Su Xin et al. studied Newsvendor Model with budgetary restraint, and found that when total fund of supply chain is large, the optimum order quantity is equal to the optimum solution of classical Newsvendor Model; when the total fund of supply chain is small, the optimum order quantity is lower than the optimum solution of classical Newsvendor Model5. The above scholars did not consider retailers have many influencing factors such as fund restraint. If producers fail to sell out fresh agricultural products, they will suffer great economic loss; if retailers with fund restraint do not work out methods to purchase agricultural products of producers, the entire supply chain of agricultural products will break and give rise to chain reaction, lead to crash of entire agricultural product market, and constitute threats to fundamental interests of farmers. In actual life, with short sales cycle and being vulnerable to deterioration and highly perishable, fresh agricultural products must be sold rapidly in purchase and sales process, to obtain higher economic value. For example, fresh vegetable, fruit and aquatic products and live livestock and poultry belong to these types. Retailers with fund restraint have to complete order through financing at external market, or purchase products of producers on credit, and repay producers after selling the products.

2 Problem description and basic assumption

The supply chain system consists of single producer and single retailer. Product produced by producers is short-life product with marginal production cost c. Market demand x is a random variable, and its probability density function is f(x). The distribution function F(x) is a monotonically increasing function. Assume \( \bar{F}(x) = 1 - F(x) \). The transaction process between producer and retailer is Stackelberg game. As a leader, producer firstly issues wholesale price w. If the retailer accepts the wholesale price, it will determine order quantity q, and then sells the product at market price p. It assumes that after completions of sales cycle T, retailer can obtain sales income, ignoring residual value of agricul-

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natural products. To simplify the Formula, assume the residual value of surplus commodities to be zero after completion of sales cycle, and do not consider out of stock loss. After retailer orders products, if the self-fund $B_0$ is not enough to pay the order amount, it needs to get loan from external bank to pay the rest amount $wq - B_0$. The loan interest rate is $r$ and the risk-free interest rate $r_f = 0 \quad (r > r_f)$. Assume the information is symmetrical, producer and retailer are risk neutral and both know loan interest rate of bank. Take

$$pA = (wq - B_0) (1 + r) - B_0$$

(1)

where $A$ means the minimum amount of commodities sold by retailer to pay off the bank loan.

On the contrary, if the ultimate market demand $x < A$, the sales income obtained by retailer after completion of sales cycle will fail to cover the bank loan. Then, the retailer will go bankrupt and its sales income will be confiscated by the bank. At this time, if the sale income is less than the bank loan, the outstanding loan may not be paid off, as described in references [7] and [8].

3 Model analysis

The expected sales volume of retailer:

$$S(q) = q - AF(x) - \int_0^q F(x) dx$$

(2)

The expected profit of retailer:

$$\pi_e = (p - w)q - pAF(x) - p\int_0^q F(x) dx - (wq - B_0)(1 + r)$$

(3)

The expected profit of producer:

$$\frac{\partial^2 q}{\partial w^2} = \left[ p^3 f'(q) + w^3 (1 + r)^3 m'(A) \right] \frac{\partial q}{\partial w} + \left[ P(1 + R)^2 m'(A) + wq(1 + r)^3 m'(A) \right] \left( q + 2w \frac{\partial q}{\partial w} \right)$$

(4)

The expected profit of bank:

$$\pi_b = (wq - B_0)(1 + r) + \int_0^q f(x) dx - (wq - B_0)$$

(5)

In Formula (5), the first item in the right means principal and interest of the loan obtained by the bank if the retailer does not go bankrupt, the second item means that sales income obtained by the bank if the retailer goes bankrupt, and the third item means risk-free return of the loan.

Theorem 1; when $0 < r < 1$, retailer has the optimum order quantity $q^*$, and $q^* = \frac{w}{p} \left\{ \frac{1 + (1 + r)n(A)}{m(A)} \right\}$

(6)

Proving: work out solution by backward induction method:

$$\frac{\partial \pi_e}{\partial q} = p - pF(q) - w - w(1 + r)n(A)$$

(7)

$$\frac{\partial \pi_e}{\partial w} = -pF(q) - w^2 (1 + r)^2 - \frac{m(A)}{P} < 0$$

(8)

where, $f(A) + Af'(A) = m(A) > 0$, $1 + Af(A) = n(A) > 0$.

The profit of retailer is a concave function of order quantity.

Take $\frac{\partial \pi_e}{\partial q} = 0$, we can get optimum order quantity $q^*$.

$$q^* = \frac{w}{p} \left\{ \frac{1 + (1 + r)n(A)}{m(A)} \right\}$$

(9)

The Theorem 1 is thus proved. According to Formula (8), the first and second derivative of wholesale price $w$ is respectively:

$$\frac{\partial q}{\partial w} = -\frac{w^2 (1 + r)^2 m(A)}{pF(q) + w^2 (1 + r)^2 m(A)}$$

(10)

$$\frac{\partial^2 q}{\partial w^2} = 2w \frac{\partial q}{\partial w} + (w - c) \frac{\partial^2 q}{\partial w^2}$$

(11)

Substitute Formula (9) and Formula (10) to Formula (11) and make simplification, we can get that the expected profit of producer $\pi_s$ is a concave function of wholesale price $w$. There is an optimum wholesale price $w^*$, then the expected profit of producer $\pi_s$ can reach the maximum value. Namely, there is the first order condition that the expected profit of producer $\pi_s$ meets the wholesale price $w^*$, $\frac{\partial \pi_s}{\partial w} = 0$, thus

$$q + (w - c) \frac{\partial q}{\partial w} = 0$$

(12)

Substitute Formula (9) to Formula (14) and make simplification, we can get optimum wholesale price of producer $w^*$,

$$w^* = \frac{p^2 q^* f(q^*) + pc[1 + (1 + r)n(A)]}{p[1 + (1 + r)n(A)] - cq^* (1 + r)^3 m(A)}$$

(13)

At this time, the expected profit of retailer:

$$\pi_e = (p - w^*)q^* - pAF(A) - p\int_0^q F(x) dx - (w^*q^* - B_0)(1 + r)$$

(14)

The expected profit of producer:

$$\pi_s = (w^* - c)q^*$$

(15)
4 Calculation examples
Assume production cost of certain fresh agricultural product $c = 2$, the wholesale price $w = 4$, market sales price $p = 10$, self-fund $B_0 = 700$, the market demand of this product $x$ conforms to uniform distribution of $[0, 1000]$, and the corresponding distribution function and density function are separately:

$$F(x) = \frac{x}{1000}, f(x) = \frac{1}{1000}$$

![Fig. 1 - The relationship between order quantity of retailer and bank interest rate](image1)

![Fig. 2 - The relationship between wholesale price of producer and bank interest rate](image2)

![Fig. 3 - The relationship between expected profit of producer and retailer and bank interest rate](image3)

Fig. 1 and Fig. 2 indicate that the order quantity of retailer with fund restraint is a function of loan interest rate of external bank, the wholesale price of producer is a function of bank interest rate, and both are decreasing functions of bank interest rate. In other words, the order quantity of retailer decreases with increase in bank interest rate, and the wholesale price of producer also decreases with increase in bank interest rate, which further proves conclusion of Proposition 1. Fig. 3 indicates that the expected profit of retailer and producer is decreasing function of loan interest rate of external bank. When the bank interest rate is 0, there is no external financing and the retailer has to purchase agricultural products with its self fund. Once, the retailer applies loan from external bank, it has to pay related interest, then the expected profit of both retailer and producer will decrease, and the decreased part is paid to the external bank. From this, we can know that adjustment of interest rate of commercial banks will influence purchase, sales and circulation of agricultural products.

5 Conclusions
According to such characteristics of fresh agricultural products as short sales cycle and high perishability, we firstly introduced the two stage supply chain consisting of single agricultural product producer and fund restraint retailer, and then analyzed the influence of bank interest rate on order quantity, wholesale price and expected profit of retailer and producer on the condition of retailer taking external loan strategy. Studies have shown that when the bank interest rate is in $(0, 0.9)$, the order quantity of agricultural products is a decreasing function of bank interest rate, namely, the order quantity of agricultural products decreases with increase in the bank interest rate; when the bank interest rate is in $(0, 1)$, the wholesale price of agricultural products is a decreasing function of bank interest rate, namely, wholesale price of agricultural products decreases with increase in the bank interest rate. When the bank interest rate is in $(0, 0.6)$, the expected profit of retailer is a decreasing function of bank interest rate, namely, the expected profit of retailer decreases with increase in the bank interest rate; when the bank interest rate is in $(0, 1)$, the expected profit of producer is a decreasing function of bank interest rate, namely, the expected profit of producer decreases with increase in the bank interest rate. Finally, with the aid of calculation examples, we simulated the variability of the above relationships. It is expected to provide application reference for practice in management of the supply chain of agricultural products.

References