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Food supply chain contingent strategies based on backup supplier and information acquirement

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ABSTRACT

This paper analyses food safety problem in food supply chain of our country firstly, then points out food safety difference between food supply chain in our country and foreign countries. Compared with foreign countries, there are potential safety hazard in food production, food logistics and the whole supply chain in food supply chain of our country. On the basis of using foreign advanced food supply chain, this paper combines the reality of our country, attempts to adopt food safety purchase, food safety cold chain logistics, food safety trace back to ensure food safety in supply chain, and constructs food safety credit administrative system to promote enterprises to implement food safety ensuring measure. Food safety purchase, food safety cold chain logistics, food safety trace back and food safety credit administrative system compose food safety ensuring system of food supply chain.

INTRODUCTION

At present, there are many potential safety hazards in agriculture input supply, food producing area environment, agricultural product production, food processing, food circulation and selling etc; there are much deficiency in food safety criterion system, detecting and authentication system, etc; there are also many problems exist in executing the law in food safety, more and more fake and forged food remains repeated emergence after repeated prohibition, the gravely food incident happens occasionally, life and health of people have got serious danger. Vegetable, fruit, meat, aquatic product and cooked meat food take up a great proportion in daily food consumption, and these foods apt to bring unsafe problem, so this paper studies and is directed primarily to these foods. In the face of the food safety of our country is backward in technique, is imperfect in supervisory system, how to take some measures in the taches of food supply chain to ensure food safety in supply chain, have realistic research meanings.

EXPERIMENTAL SECTION

2.1. Model assumptions

Based on option theory, we study a two-stage supply chain with two food suppliers leading by one retailer. Operational performance in four decisions mode is explored based on supply disruption information. The food supplier is in the face of supply disruption and the backup supplier is completely reliable without capacity constraints. As shown in Figure 1, firstly, retailer to the backup supplier ordering predetermined capacity of K, that is, pre-process options. Then to the food supplier ordering Q, finally to the backup food suppliers ordering K_1(food supplier without disruption supply) or K_2 (food supplier in disruption supply state) in the capacity constraint conditions, this is option execution process. Food supplier acquisition supply disruption information sooner or later can be divided into four modes, perfect information model, advance-acquirement information mode, post-acquirement information and no information model.

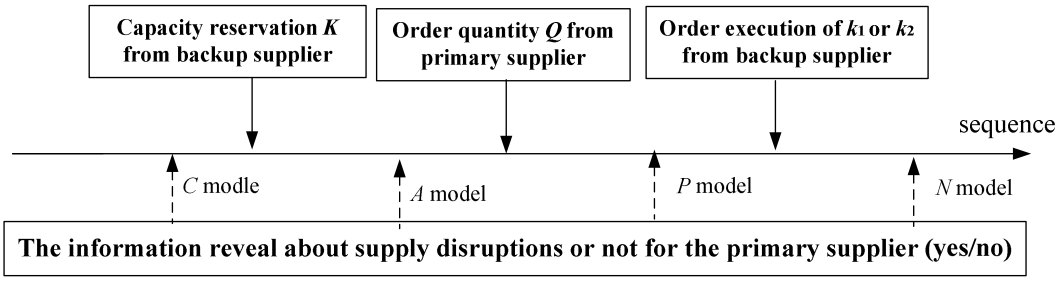

Figure 1. Emergency decision based on backup supplier and supply disruption information

2.2. Model parameters

(1) Retailer orders Q from food supplier. In the event of disruption for food supplier the retailer received nothing; otherwise the actual deliveries all of Q, i.e. supply uncertainty of food supplier is of "all-or-noting" type. We consider the probability of supply disruptions is (1-γ), the probability of supply normal state is γ, called by the reliability coefficient, with $0<\gamma<1$.

(2) Retailer pays the unit cost of λc when ordering the food supplier, $0\leq\lambda\leq1$. Then retailers pay $(1-\lambda)c$ when supply state is normal and no longer pay in supply disruption state .$\lambda>0$ mainly applied to purchase bio-pharmaceutical products or other special products[7,18,19]. $\lambda=1$ represents the food supplier is the retailer internal corporate, $\lambda=0$ represents the food supplier is the retailers outside enterprise, $0<\lambda<1$ represents equity investments or mutual relationship between supplier and retailer.

(3) Retailer reserves capacity K from backup supplier, the unit cost is $c_{o.}$ Then according to the delivery from the food supplier the retailer determines the executive quantity under the reservation constraint. Retailer ordersk_1 from backup supplier when food supplier in normal state, and order $k_2$when food supplier in disruption state. The unit execution cost from backup supplier is $c_{e.}$,with $c<c_o+c_{e.}$

(4) Based on food supplier state and backup supplier capacity constraints, retailer determines the executive order from backup supplier. Retailer ordersk_1 from backup supplier when food supplier is in normal state, and orders$k_2$when food supplier is in disruption state.

(5) Customer demand is dependent on the sales price, thus inverse demand function is $p=a-bQ$, $a,b$are both greater than 0.Assuming$a>c_o+c_{e.}$

In addition, the superscript * indicates optimal value, superscript ' represents one derivative, and superscript "denotes second derivative. Subscript P, A, N and C respectively represent post-acquirement information, advance-acquirement information, missing information and perfectly information.

3. Operation performance based on backup supplier under post-acquirement information model

Under post-acquirement information P mode, firstly the retailer reserves capacity K from backup supplier, then orders Q from food supplier and obtains the information of whether food supplier is under disruption, finally executes to orderk_1 from backup supplier under capacity constrains(No disruption occurs to food supplier) or k_2 (Disruption occurs to food supplier). $K \to Q \to Yes/no \to k_1(k_2)$ stands for decision sequel, where arrows indicate the order, and yes/no stand for whether food supplier is normal. The sequence of backup supplier's capacity reservation $K$and food supplier's order Q has on impact on decision variables and optimal profit functions, we merge the two processes into one. So the decision sequence can be described as $K \circ Q \to Yes/no \to k_1(k_2)$, in which circles indicate decision-making simultaneously.

Based on the sub-game perfect Nash equilibrium theory, usingbackward induction process, the retailer firstly determines the executive quantity of backup supplier, then the order quantity of food supplier and finally the capacity reservation of backup supplier.

3.1. Executive order quantity of backup supplier

Knowing Q and K, we can obtaink_1, which represents the order quantity that retailer order from backup supplier without disruptions for food supplier, andk_2 which represents the order quantity that food supplier order from backup supplier with disruptions respectively.

(1) Executive quantity of backup supplier without disruptions

$k_1^* = \arg\max_{0\le k_1\le K} \pi_1(k_1 \mid Q,K) = \arg\max_{0\le k_1\le K}(a-b(Q+k_1))(Q+k_1) - c_e k_1 - cQ - c_o K$ (1)

$$\pi_1'(k_1 \mid Q,K) = a - c_e - 2b(Q+k_1)$$

If $Q \le (\frac{a-c_e}{2b} - K)^+$, then

$k_1^* = K$ (2)

If $(\frac{a-c_e}{2b} - K)^+ \le Q \le \frac{a-c_e}{2b}$, then

$k_1^* = \frac{a-c_e}{2b} - Q$ (3)

If $Q \ge \frac{a-c_e}{2b}$, then

$k_1^* = 0$ (4)

(2) Executive quantity of backup supplier with disruptions

$k_2^* = \arg\max_{0\le k_2\le K} \pi_2(k_2 \mid Q,K) = \arg\max_{0\le k_2\le K}(a-bk_2)k_2 - c_e k_2 - \lambda cQ - c_o K$ (5)

$$\pi_2'(k_2) = a - c_e - 2bk_2$$

If $0 \le K \le \frac{a-c_e}{2b}$, then

$k_2^* = K$ (6)

If $K \ge \frac{a-c_e}{2b}$, then

$k_2^* = \frac{a-c_e}{2b}$ (7)

Since $k_1^* \le \frac{a-c_e}{2b}$ and $k_2^* \le \frac{a-c_e}{2b}$, so $k_1^* \le K$ and $k_2^* \le K$, therefore $K \le \frac{a-c_e}{2b}$, $k_2^* = K$.

3.2.Decision of order quantity of food supplier and reservation capacity of backup supplier

Food and backup food suppliers both supply the retailer without disruptions to food supplier, where the total delivery is$Q$+k_1.Only backup supplier deliveries the retailer under disruptions, where the total delivery is k_2。

Case 1: As $Q \le \frac{a-c_e}{2b} - K$, $k_1^* = K$. The retailer's profit function is gained,

$\max \pi(Q,K) = \gamma[(a-b(Q+K))(Q+K) - cQ - c_e K] + (1-\gamma)[(a-bK)K - c_e K - \lambda cQ] - c_o K$ (8)

From (8), we have

$$\pi_Q'(Q,K) = \gamma[(a-2b(Q+K)) - c] + (1-\gamma)(-\lambda c)$$

$$\pi_K'(Q,K) = \gamma[a-2b(Q+K) - c_e] + (1-\gamma)(a-2bK-c_e) - c_o$$

If $\gamma \ge \frac{\lambda c}{c_e - c + \lambda c}$, i.e. $c_e \ge c + (1-\gamma)\lambda c/\gamma$, then

$Q^* = \frac{a-c_e}{2b} - K^*$ (9)

$K^* = [\frac{a-c_e-c_o/(1-\gamma)}{2b}]^+$ (10)

If $\frac{\lambda c}{c_e + c_o - c + \lambda c} \le \gamma < \frac{\lambda c}{c_e - c + \lambda c}$, i.e. $c_e < c + (1-\gamma)\lambda c / \gamma \le c_e + c_o$, then

$$Q^* = \frac{a - c - (1-\gamma)\lambda c / \gamma}{2b} - K^* \quad (11)$$

$$K^* = [\frac{a + \lambda c - (c_e + c_o - \gamma c)/(1-\gamma)}{2b}]^+ \quad (12)$$

If $\gamma < \frac{\lambda c}{c_e + c_o - c + \lambda c}$, i.e. $c + (1-\gamma)\lambda c / \gamma > c_e + c_o$, then

$$Q^* = 0 \quad (13)$$

$$K^* = \frac{a - c_e - c_o}{2b} \quad (14)$$

Case 2: As $\frac{a-c_e}{2b} - K \le Q \le \frac{a-c_e}{2b}$, then $k_1^* = \frac{a-c_e}{2b} - Q$. We can get the retailer's profit function,

$$\begin{aligned} \max \pi(Q,K) &= \gamma[(a - \frac{a-c_e}{2b})\frac{a-c_e}{2b} - cQ - c_e(\frac{a-c_e}{2b} - Q)] + (1-\gamma)[(a-bK)K - c_eK - \lambda cQ] - c_oK \\ &= \gamma(ce - c)Q + \gamma[(a - \frac{a-c_e}{2b})\frac{a-c_e}{2b} - c_e\frac{a-c_e}{2b}] + (1-\gamma)[(a-bK)K - c_eK - \lambda cQ] - c_oK \end{aligned} \quad (15)$$

From (15), we have

$$\pi'_Q(Q,K) = \gamma(c_e - c) - (1-\gamma)\lambda c$$
$$\pi'_K(Q,K) = (1-\gamma)(a - 2bK - c_e) - c_o$$

If $\gamma \ge \frac{\lambda c}{c_e - c + \lambda c}$, then $c_e \ge c + (1-\gamma)\lambda c / \gamma$. Now,

$$Q^* = \frac{a-c_e}{2b} \quad (16)$$

$$K^* = [\frac{a - c_e - c_o/(1-\gamma)}{2b}]^+ \quad (17)$$

Else,

$$Q^* = \frac{a-c_e}{2b} - K^* \quad (18)$$

$$K^* = [\frac{a - c_e - c_o/(1-\gamma)}{2b}]^+ \quad (19)$$

We should minimize pre-ordering costs and increase the punishment for food supplier when the disruption probability of food supplier is large. In general, paying pre-ordering costs and punitive measures are both available if the food supplier is under disruption. Which way matters depends on the relationship between retailers and food food suppliers and product characteristics and so on. The retailer generally pays the pre-ordering costs in advance in order to establish a good reputation even though it will cause profit lossif the disruption is caused by the complex of product or process especially in the early stage or other uncontrollable factors. But the retailer will take punitive measures if the disruption is caused by food supplier's failures or ill management.

CONCLUSION

Food safety purchase prevent deleterious food from entering supply chain; food cold chain logistics guarantees safety of food in the course of logistics; food safety trace back can find food harm source and other food which has the same harm, and can remove the harm source and regain harm food in time; Food safety credit administrative system can promote enterprise in food supply chain implement food safety ensuring measures actively.

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