Research Article

Research on Cooperation Strategy of Enterprises' Quality and Safety in Food Supply Chain

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In order to prevent and control risk factors which harm the quality and safety of the food supply chain effectively and reduce the probability of food safety incidents, this paper investigated on some problems of the upstream and downstream enterprises of the food supply chain under the three different forms of cooperation based on the neoclassic economics and game theory method. These problems include the effectiveness of the quality and safety efforts, the profits, the effect of the losses that the food safety incidents caused on the quality efforts' efficacy, and the social welfare comparison. Meanwhile, we constructed evolutionary game model to analyze the macro and micro factors that influenced the cooperation strategy and demonstrated the effect of diversity of decision-making parameters on evolution results based on numerical simulation. By the theoretical and simulation analysis, we found that (1) the quality efforts' efficacy, the profits, the sensitivity coefficient of the quality efforts efficiency to the losses, and the social welfare without thinking about the externality all met their maximum under the full cooperation situation; (2) strengthening supervision over the source of the food supply chain can reduce the probability of food safety incidents; (3) macro and micro environment will be the important basis for companies' decision-making on cooperation strategy in the food supply chain.

1. Introduction

Food safety is related to the life and health of the whole nation, the healthy development of the economy, social harmony and stability, and the image of state and government. However, the food safety incidents that many factors caused have happened frequently in recent years. These factors included the food markets failures due to the food markets' externality and "lemon market effect" that information asymmetry in food markets caused [1–3], the mismatch between the costs and the benefits made the center of interest gravity shift toward the downstream of the industry, food companies paid too much attention to the market share and put the risks which were accumulated by the upstream interests contradiction to the extreme through the transmission of leverage effect, and so forth [4, 5]. The frequent occurrences of food safety accidents have led to consumers' extreme lack of social trust in food safety and weakened consumers' willingness to spend on food [6] and numerous consumers have been in a state of panic.

Risk factors of food safety throughout each link of the whole supply chain are from the source's supply of raw materials, the cultivation and breeding of agricultural products,

the production and processing, and logistics distribution to retail terminal. Risk factors existing in each link (e.g., abuse of pesticides in the planting and breeding links and use of food additives excessively in the production and processing links) would pass on the food supply chain, and then it produced the agglomeration and amplification effects and led to the occurrence of food safety incidents eventually [7–12]. Therefore, it is not only the tasks of one side or an enterprise, but the responsibility of all the main participant bodies in the food supply chain to ensure the food safety.

Many factors, for example, information asymmetry [13–16] and the interest game imbalance between all the main participant bodies in the food supply chain [17], could induce the occurrence of the "adverse selection" and "moral hazard" behavior which harmed the food safety. The adverse selection problems in the food supply chain could be solved effectively by way of investigating the main participant bodies' past performance and business reputation and the main participant bodies to adopting a third-party certification, establishing long-term strategic cooperative partnership between the main participant bodies, transforming the enterprise's

business philosophy, and so forth [18–20]. The moral hazard problems in the food supply chain could be solved effectively by way of establishing the appropriate incentive and supervision mechanism [21–24]. From the perspective of food supply chain, it could realize the goal of enhancing the food supply chain's ability to effectively resist and control food safety risk through establishing synergy mechanism among all the main participants [25–31]. However, the literatures [25–31] just put forward a thinking framework and lack of concrete and in-depth research on the synergy strategies between the main participant bodies in the food supply chain.

It is exactly based on the above consideration that this paper tries from the aspect of food supply chain to realize close cooperation between all of the links (the node enterprises) in the food supply chain through establishing the cooperation, incentive, and supervision mechanism and to reach the goals for preventing and controlling risk factors which harm the quality and safety of the food supply chain effectively and reducing the probability of food safety incidents. This paper is structured as follows. Section 2 presents some assumptions, defines the notation used in this paper, presents the profit function models of enterprises in the food supply chain, and discusses the profit function models of enterprises in the food supply chain. Section 3 highlights the effects of the macro and micro factors on the enterprises' collaboration strategy for the quality and safety through numerical simulations. The final section contains concluding remarks.

2. The Design of Cooperation, Incentive, and Supervision Contract Constraint Mechanism

2.1. The Establishment of the Theoretical Model

Assumption 1. This paper analyzes the problems about quality and safety cooperation between the upstream enterprise A and the downstream enterprise B from the perspective of food supply chain. Enterprise B is the retail terminal that has a certain processing capability relative to the enterprise A . Meanwhile both enterprises A and B are regulated by the governmental supervision department's quality and safety.

Assumption 2. Both enterprises A and B put the quality efforts as decision variables and make a choice between quality efforts cooperation and noncooperation in order to achieve the double-edged optimization goals, which are the food security and the profit maximization.

Assumption 3. The effectiveness of the quality efforts, the profits, and the social welfare of both enterprises A and B are all different under the different cooperation modalities. The quality efforts' efficacy of enterprise A will have certain impact on enterprise B , and vice versa.

Assumption 4. There is no comparison between the extents of the different food commodities' quality efforts. However, the quality effort efficiency (the probability of food safety incidents) can be compared in the different food commodities.

Assumption 5. Products of enterprises A and B belong to the necessities. The market is the imperfect competition market. And the demand for food is a linear function of food price. Meanwhile, food inventories of both enterprises A and B are zero.

Assumption 6. The unit food quality effort (the amount of per unit food quality and safety events that can be reduced) is constant under certain conditions. And the total quality efforts of both enterprises A and B are linear functions of food production.

Assumption 7. The quality effort cost is a monotone increasing function of the quality effort efficiency, and the marginal cost of quality effort increases with the increasing of the quality effort efficiency. The inputs on quality efforts have no impact on the food production cost.

Assumption 8. The average number of quality and safety events of per unit food of both enterprises A and B is N_A, N_B in one year. The loss that the average quality and safety events of per unit food caused each time is S . The average number of quality and safety events of the unit food of both enterprises A and B that can be reduced in one year is $\Delta N_A, \Delta N_B$ for quality effort. The quality effort efficiency of enterprise is $f_{i=A,B}$, and $0 \leq f_i = \Delta N_i / N_i$ ($i = A, B$) < 1 . The retail price of food is p , the demand for food is Q , the total quality efforts of both enterprises A and B are $E_i(Q)$, and $E_i(Q) = \Delta N_i Q$. The total quality efforts costs of both enterprises A and B are $C(f_i)$, which satisfies $\partial C(f_i) / \partial f_i > 0$, $\partial^2 C(f_i) / \partial f_i^2 > 0$, $C(0) = 0$, and $C(1) = +\infty$. In general, we can assume that $C(f_i)$ is the quadratic function of the quality effort efficiency according to the literatures [15, 16], which satisfies $C(f_i) = (1/2)nf_i^2$, and n is on behalf of the extent of the quality effort. It is indicated that the greater the n is, the higher the quality effort cost is. The production cost of per unit food is c_i , and the wholesale price of food is c_p .

We can construct the profit function of enterprise A based on the above assumptions, which satisfies $L_A = [c_p - c_A - N_A S(1 - f_A)]Q - (1/2)nf_A^2$, and assume that the market demand for high-quality food satisfies $Q = N - ap$, N on behalf of market capacity and a on behalf of the sensitivity coefficient of demand price. Thus the profit function of enterprise A can be represented as follows:

$$L_A = [c_p - c_A - N_A S(1 - f_A)](N - ap) - \frac{1}{2}nf_A^2. \quad (1)$$

In the same way, the profit function of enterprise B can be represented as follows:

$$L_B = [p - c_p - c_B - N_B S(1 - f_B)](N - ap) - \frac{1}{2}nf_B^2. \quad (2)$$

The game between enterprises A and B is divided into two stages. The first stage is about the level of quality effort; the second stage is about the food price. The two-stage game can

FIGURE 1: The game process of three forms.

be divided into three forms (as shown in Figure 1) according to the different forms of cooperation between enterprises, as follows.

The First Form. Noncooperation, namely, NC, means that both enterprises A and B are uncooperative in the quality, safety, and price. The food price of enterprise B needs to be determined based on the wholesale price of enterprise A, and the basis of their decision-making is based on profit maximization.

The Second Form. Semicooperation, namely, BC, means that both enterprises A and B are just cooperative in the quality and safety, and the profit maximization is the basis of their food price decision-making. However, the goal to maximize the profits of the entire food supply chain is the basis of their quality efforts investment decision-making.

The Third Form. Cooperation, namely, HC, means that the complete trust working relationship between enterprises A and B has been established. The goal to maximize the profits of the entire food supply chain is the basis of their retail price of food and quality efforts investment decision-making, but c_p does not exist at the moment.

Let us solve the above problems based on the backward induction.

(1) *The First Form: The Form of Noncooperation.* The food sale price decision-making of enterprise B is based on the profit maximization under the situation of noncooperation.

Proposition 9. *The downstream enterprise's quality efforts efficiency is lower than the upstream enterprise when $N_A = N_B$ under the situation of noncooperation.*

Demonstration. Let $\partial L_B / \partial p = (N - ap) - a[p - c_p - c_B - N_B S(1 - f_B)] = 0$; thus p_{NC}^* and Q_{NC}^* can be obtained; bring

them into (1), and let $\partial L_A / \partial c_p = 0$; thus c_{pNC}^* , p_{NC}^* , and Q_{NC}^* can be obtained, as follows:

$$\begin{aligned}
 c_{pNC}^* &= \frac{N + a[c_A - c_B + N_A S(1 - f_A) - N_B S(1 - f_B)]}{2a} \\
 p_{NC}^* &= \frac{3N + a[c_A + c_B + N_A S(1 - f_A) + N_B S(1 - f_B)]}{4a}, \\
 Q_{NC}^* &= \frac{N - a[c_A + c_B + N_A S(1 - f_A) + N_B S(1 - f_B)]}{4}.
 \end{aligned} \quad (3)$$

Bring Q_{NC}^* into (1) and (2); due to $\partial L_A / \partial f_A < 0$, $\partial L_B / \partial f_B < 0$; thus, letting $\partial L_A / \partial f_A = 0$, $\partial L_B / \partial f_B = 0$, f_A , f_B can be obtained, as follows:

$$\begin{aligned}
 f_A &= \frac{N_A S \{N - a[c_A + c_B + N_A S + N_B S(1 - f_B)]\}}{4n - aN_A^2 S^2}, \\
 f_B &= \frac{N_B S \{N - a[c_A + c_B + N_B S + N_A S(1 - f_A)]\}}{8n - aN_B^2 S^2}.
 \end{aligned} \quad (4)$$

With (4), the optimal values of quality efforts efficiency of both enterprises A and B can be obtained, as follows:

$$\begin{aligned}
 f_{ANC}^* &= \frac{2N_A S [N - a(c_A + c_B + N_A S + N_B S)]}{8n - aS^2 (N_B^2 + 2N_A^2)}, \\
 f_{BNC}^* &= \frac{N_B S [N - a(c_A + c_B + N_A S + N_B S)]}{8n - aS^2 (N_B^2 + 2N_A^2)}.
 \end{aligned} \quad (5)$$

Therefore, $f_{ANC}^* = f_{BNC}^*$ when $N_A = N_B$. Proposition 9 has been demonstrated to be correct.

(2) *The Second Form: The Form of Semicooperation.* Quality efforts investment decision-making is made by both enterprises A and B under the situation of semicooperation. But the food price decision-making is, respectively, made by themselves; namely, the game of the second stage is the same as the situation of noncooperation; meanwhile, the equation that $c_{pBC}^* = c_{pNC}^*$, $p_{BC}^* = p_{NC}^*$, and $Q_{BC}^* = Q_{NC}^*$ can be obtained.

Proposition 10. *There exists local maximum in the overall profits of the food supply chain under the situation of semicooperation, and the downstream enterprise's quality efforts efficiency is equal to the upstream enterprise when $N_A = N_B$.*

Demonstration. Quality efforts investment decision-making will be made by both enterprises A and B in order to achieve the goal that maximizes the overall profits of the food supply chain of the first stage. The profit functions of enterprises and the whole food supply chain at the moment are the following:

$$\begin{aligned}
 L_{ABC} &= \frac{\{N - a[c_A + c_B + N_A S(1 - f_A) + N_B S(1 - f_B)]\}^2}{8a} \\
 &\quad - \frac{1}{2} n f_A^2 \\
 L_{BBC} &= \frac{\{N - a[c_A + c_B + N_A S(1 - f_A) + N_B S(1 - f_B)]\}^2}{16a} \\
 &\quad - \frac{1}{2} n f_B^2 \\
 L_{BC} &= \frac{3\{N - a[c_A + c_B + N_A S(1 - f_A) + N_B S(1 - f_B)]\}^2}{16a} \\
 &\quad - \frac{1}{2} n (f_A^2 + f_B^2).
 \end{aligned} \tag{6}$$

Thus that *Hessian Matrix* can be obtained:

$$\begin{aligned}
 H_{BC} &= \begin{pmatrix} \frac{\partial^2 L_{BC}}{\partial f_A^2} & \frac{\partial^2 L_{BC}}{\partial f_A \partial f_B} \\ \frac{\partial^2 L_{BC}}{\partial f_B \partial f_A} & \frac{\partial^2 L_{BC}}{\partial f_B^2} \end{pmatrix} \\
 &= \begin{pmatrix} \frac{3aN_A^2 S^2}{8} - n & \frac{3aN_A N_B S^2}{8} \\ \frac{3aN_A N_B S^2}{8} & \frac{3aN_B^2 S^2}{8} - n \end{pmatrix}.
 \end{aligned} \tag{7}$$

Consider $|H_{BC}| = n[n - 3aS^2(N_A^2 + N_B^2)/8] > 0$. Therefore, there exists local maximum in the overall profits of the food supply chain. Let $\partial L_{BC}/\partial f_A = 0$, $\partial L_{BC}/\partial f_B = 0$; thus the optimal values of quality efforts efficiency of both enterprises

A and B can be obtained by solving the simultaneous equations, as follows:

$$\begin{aligned}
 f_{ABC}^* &= \frac{3N_A S [N - a(c_A + c_B + N_A S + N_B S)]}{8n - 3aS^2(N_B^2 + N_A^2)}, \\
 f_{BBC}^* &= \frac{3N_B S [N - a(c_A + c_B + N_A S + N_B S)]}{8n - 3aS^2(N_B^2 + N_A^2)}.
 \end{aligned} \tag{8}$$

Therefore, $f_{ABC}^* = f_{BBC}^*$ when $N_A = N_B$. Proposition 10 has been demonstrated to be correct.

(3) *The Third Form: The Form of Cooperation.* The full trust working relationship between enterprises has been completely established under the situation of cooperation. Thus the food price and the quality effort efficiency can be determined by both enterprises A and B.

Proposition 11. *There exists local maximum in the overall profits of the food supply chain under the situation of cooperation, and the downstream enterprise's quality effort efficiency is equal to the upstream enterprise when $N_A = N_B$.*

Demonstration. The sale price of food is determined by both enterprises A and B in the second stage and the profit function of the whole food supply chain is as follows;

$$\begin{aligned}
 L_{HC} &= \{p - [c_A + c_B + N_A S(1 - f_A) + N_B S(1 - f_B)]\} \\
 &\quad \cdot (N - ap) - \frac{1}{2} n (f_A^2 + f_B^2).
 \end{aligned} \tag{9}$$

Let $\partial L_{HC}/\partial p = 0$, and p_{HC}^* , Q_{HC}^* can be obtained, as follows:

$$\begin{aligned}
 p_{HC}^* &= \frac{N + a[c_A + c_B + N_A S(1 - f_A) + N_B S(1 - f_B)]}{2a} \\
 Q_{HC}^* &= \frac{N - a[c_A + c_B + N_A S(1 - f_A) + N_B S(1 - f_B)]}{2}.
 \end{aligned} \tag{10}$$

Bring p_{HC}^* and Q_{HC}^* into (9), and Hessian Matrix can be obtained, as follows:

$$\begin{aligned}
 H_{HC} &= \begin{pmatrix} \frac{\partial^2 L_{HC}}{\partial f_A^2} & \frac{\partial^2 L_{HC}}{\partial f_A \partial f_B} \\ \frac{\partial^2 L_{HC}}{\partial f_B \partial f_A} & \frac{\partial^2 L_{HC}}{\partial f_B^2} \end{pmatrix} \\
 &= \begin{pmatrix} \frac{aN_A^2 S^2}{2} - n & \frac{aN_A N_B S^2}{2} \\ \frac{aN_A N_B S^2}{2} & \frac{aN_B^2 S^2}{2} - n \end{pmatrix}.
 \end{aligned} \tag{11}$$

Therefore, there exists local maximum in the overall profits of the food supply chain due to $|H_{HC}| = n[n - (aS^2(N_A^2 + N_B^2))/2] > 0$. Let $\partial L_{HC}/\partial f_A = 0$, $\partial L_{HC}/\partial f_B = 0$; thus

the optimal values of quality efforts efficiency of both enterprises A and B under the situation of cooperation can be obtained through solving the simultaneous equations, as follows:

$$\begin{aligned} f_{AHC}^* &= \frac{N_A S [N - a(c_A + c_B + N_A S + N_B S)]}{2n - aS^2(N_B^2 + N_A^2)}, \\ f_{BHC}^* &= \frac{N_B S [N - a(c_A + c_B + N_A S + N_B S)]}{2n - aS^2(N_B^2 + N_A^2)}. \end{aligned} \quad (12)$$

Therefore $f_{AHC}^* = f_{BHC}^*$ when $N_A = N_B$. Proposition 11 has been demonstrated to be correct.

2.2. The Theoretical Analysis of Contact Mechanism Design

2.2.1. Interaction Effects between the Upstream and Downstream Enterprises

Proposition 12. *The extent of quality efforts for food safety must be greater than a certain value, namely, δ , and then the quality efforts can be productive.*

Demonstration. With (4), the following equations can be obtained due to $0 \leq f_i = \Delta N_i / N_i$ ($i = A, B$) < 1 :

$$\begin{aligned} 4n &> N_A S \{N - a[c_A + c_B + N_B S(1 - f_B)]\}, \\ 8n &> N_B S \{N - a[c_A + c_B + N_A S(1 - f_A)]\}. \end{aligned} \quad (13)$$

The equation $N - a[c_A + c_B + N_B S(1 - f_B)]$ or $N - a[c_A + c_B + N_A S(1 - f_A)]$ can be represented as a kind of food demands, which is when the upstream or downstream enterprise makes quality efforts and downstream or upstream enterprise is not profitable. The equation $N_A S \{N - a[c_A + c_B + N_B S(1 - f_B)]\}$ or $N_B S \{N - a[c_A + c_B + N_A S(1 - f_A)]\}$ can be represented as a loss that these demands caused in the food safety incidents. Only when the extent of quality efforts is greater than the loss that the food safety incidents caused can the quality efforts efficiency be achieved. Therefore, quality efforts of enterprises can achieve some kind of effectiveness only when $n > (1/4)N_A S \{N - a[c_A + c_B + N_B S(1 - f_B)]\}$; namely, $\delta = (1/4)N_A S \{N - a[c_A + c_B + N_B S(1 - f_B)]\}$. Proposition 12 has been demonstrated to be correct.

Proposition 13. *If one wants to reduce the probability of food safety incidents when the average number of quality and safety events of per unit food of the upstream and downstream enterprises in one year is the same, one should pay attention to strengthening regulation over the source of the food supply chain. The same number of quality efforts investments can achieve more quality efforts effectiveness in the upstream enterprise.*

Demonstration. We can find that the equation $f_A \geq f_B$ can always be obtained when $N_A = N_B$ through comparing the quality efforts efficiency of enterprises A and B under the three different forms of cooperation. Therefore, Proposition 13 has been demonstrated to be correct.

Proposition 14. *The quality efforts behavior of the upstream or downstream enterprises can encourage the downstream or upstream enterprises to carry out quality efforts.*

Demonstration. It can be seen from the inequality $4n > N_A S \{N - a[c_A + c_B + N_B S(1 - f_B)]\}$ that the improvement of the quality efforts efficiency of enterprise B will increase the difficulty of enterprise A obtaining the same quality efforts efficiency. Therefore, enterprise A is bound to increase the amount of quality efforts investment if it wants to achieve the original quality efforts efficiency due to the reason that the enterprise A shares part of the quality effort costs for enterprise B . It can be seen from the inequality $4n > N_A S \{N - a[c_A + c_B]\}$ that the quality efforts efficiency of enterprise A will be improved obviously when $\lim_{f_B \rightarrow 0} N_B S(1 - f_B) = 0$. Thus, Proposition 14 has been demonstrated to be correct.

Proposition 15. *The extent of quality efforts is directly proportional to the average number of quality and safety events of per unit food of an enterprise in one year and is inversely proportional to the average number of quality and safety events of per unit food of another enterprise in one year. Namely, for food companies, the more the average number of quality and safety events of the unit food in one year, the greater the resistance of that enterprise to carry out quality efforts.*

Demonstration. Assume that the extents of quality efforts of the two main participant bodies are the same. It can be seen from the inequality $4n > N_A S \{N - a[c_A + c_B + N_B S(1 - f_B)]\}$ that n is directly proportional to N_A and is inversely proportional to N_B . In the same way, it can be seen from the inequality $8n > N_B S \{N - a[c_A + c_B + N_A S(1 - f_A)]\}$ that n is inversely proportional to N_A and is directly proportional to N_B . If the difficulty coefficients of quality efforts of the two main participant bodies are not the same, then there exists n_A and n_B simultaneously; n_A is directly proportional to N_A and is inversely proportional to N_B ; n_B is inversely proportional to N_A and is directly proportional to N_B . Therefore, Proposition 15 has been demonstrated to be correct.

2.2.2. *The Comparison of the Average Number of Quality and Safety Events of per Unit Food of the Whole Food Supply Chain in One Year and the Enterprises' Quality Efforts Efficiency under Different Forms of Cooperation.* After the enterprises A and B carried out quality efforts, the average number of quality and safety events of per unit food of the whole food supply chain in one year under different forms of cooperation, respectively, is as follows:

$$\begin{aligned} N_{NC}^* &= N_A (1 - f_{ANC}^*) + N_B (1 - f_{BNC}^*) \\ &= \frac{8n(N_A + N_B) - S(N_B^2 + 2N_A^2)[N - a(c_A + c_B)]}{8n - aS^2(N_B^2 + 2N_A^2)} \\ N_{BC}^* &= N_A (1 - f_{ABC}^*) + N_B (1 - f_{BBC}^*) \\ &= \frac{8n(N_A + N_B) - 3S(N_B^2 + N_A^2)[N - a(c_A + c_B)]}{8n - 3aS^2(N_B^2 + N_A^2)} \end{aligned}$$

$$\begin{aligned}
N_{HC}^* &= N_A (1 - f_{AHC}^*) + N_B (1 - f_{BHC}^*) \\
&= \frac{2n(N_A + N_B) - S(N_B^2 + N_A^2)[N - a(c_A + c_B)]}{2n - aS^2(N_B^2 + N_A^2)}.
\end{aligned} \tag{14}$$

Proposition 16. *The average number of quality and safety events of per unit food of the whole food supply chain in one year will decrease with the increase of the extent of cooperation.*

Demonstration. It can be seen from the inequality $N_{NC}^* - N_{BC}^* > 0$ and $N_{BC}^* - N_{HC}^* > 0$ that $N_{NC}^* > N_{BC}^* > N_{HC}^*$. Therefore, Proposition 16 has been demonstrated to be correct.

Proposition 17. *The quality efforts efficiency of enterprises in the state of cooperation is higher than that in the state of noncooperation. Therefore, only with strengthening the quality efforts cooperation between upstream and downstream enterprises can the higher effectiveness on guaranteeing food safety be achieved in the process of strengthening the food safety guarantee.*

Demonstration. It can be seen from the inequality $f_{ABC}^* - f_{ANC}^* > 0$ and $f_{AHC}^* - f_{ABC}^* > 0$ that $f_{AHC}^* > f_{ABC}^* > f_{ANC}^*$. And the inequality $f_{BHC}^* > f_{BBC}^* > f_{BNC}^*$ can be obtained in the same way. Therefore, Proposition 17 has been demonstrated to be correct.

2.2.3. The Influence of the Loss S That Food Quality and Safety Incidents Caused on the Quality Efforts Efficiency. Assume that $N_A = N_B = 1$, $c_A = c_B = 0$, and $a = 1$ in order to simplify the calculation; thus $\overline{f_{ANC}^*} = 2S(N - 2S)/(8n - 3S^2)$, $\overline{f_{BNC}^*} = S(N - 2S)/(8n - 3S^2)$, $\overline{f_{NC}^*} = 3S(N - 2S)/(8n - 3S^2)$, $\overline{f_{ABC}^*} = 3S(N - 2S)/(8n - 6S^2)$, $\overline{f_{BBC}^*} = 3S(N - 2S)/(8n - 6S^2)$, $\overline{f_{BC}^*} = 6S(N - 2S)/(8n - 6S^2)$, $\overline{f_{AHC}^*} = S(N - 2S)/(2n - 2S^2)$, $\overline{f_{BHC}^*} = S(N - 2S)/(2n - 2S^2)$, and $\overline{f_{HC}^*} = S(N - 2S)/(n - S^2)$. It can be seen from the above formula that the quality efforts efficiency is affected by the S fluctuations.

Proposition 18. *The quality efforts efficiency of the whole supply chain is the highest under the situation that enterprise A cooperates with enterprise B and is the lowest under the noncooperation situation.*

Demonstration. It can be seen from the inequality $\overline{f_{HC}^*} > \overline{f_{BC}^*} > \overline{f_{NC}^*}$ that Proposition 18 is obviously correct.

Proposition 19. *The quality efforts efficiency is directly proportional to the loss S that the average quality and safety events of per unit food caused each time under the different cooperation modalities. If the enterprise A is uncooperative with the enterprise B, then the larger value of the quality efforts efficiency can be obtained, and the increments of the quality efforts efficiency gradually increase when S is relatively large. If the enterprise A is cooperative with the enterprise B, then the larger value of the quality efforts efficiency can be*

obtained, but the increments of the efficiency of quality efforts gradually decrease when S is relatively small. And the sensitivity coefficient of the quality efforts efficiency of the food supply chain to S is the highest in the case of cooperation and is the lowest in the case of noncooperation.

Demonstration. Take the noncooperation situation for example. It can be seen from the equation $\partial \overline{f_{NC}^*} / \partial S = (9NS^2 - 96nS + 24nN)/(8n - 3S^2)^2$ that $\overline{f_{NC}^*}$ is directly proportional to S when $9NS^2 - 96nS + 24nN > 0$. Let $f(S) = 9NS^2 - 96nS + 24nN$; thus $\Delta = 32n - 3S^2$ when $f(S) = 0$.

- (1) There are no intersection points between the curve $\partial \overline{f_{NC}^*} / \partial S$ and the S axis (as curve I which is shown in Figure 2) when $\Delta < 0$; namely, the inequality $\partial \overline{f_{NC}^*} / \partial S > 0$ is always stand-up, and $\overline{f_{NC}^*}$ is directly proportional to S . Curve II can be derived from curve I. It can be seen from curve II that $\Delta \overline{f_{NC}^*}$ is decreasing with the increase of S when S is relatively small, and $\Delta \overline{f_{NC}^*}$ is increasing with the increase of S due to the reason that enterprises increase the quality efforts investment when S is relatively large which results in the increasing of the probability of bankruptcy crisis to be faced by food companies (e.g., Sanlu Milk Powder Incident in 2008).
- (2) The curve $\partial \overline{f_{NC}^*} / \partial S$ intersects the S axis at two points when $\Delta > 0$, namely, S^- and S^+ (as curve II which is shown in Figure 2). When $S \in (0, S^-)$, the inequality $\partial \overline{f_{NC}^*} / \partial S > 0$, $\partial^2 \overline{f_{NC}^*} / \partial S^2 < 0$ can be obtained; thus $\overline{f_{NC}^*}$ is directly proportional to S ; $\Delta \overline{f_{NC}^*}$ is decreasing with the increase of S . When $S = S^-$, the equation $\partial \overline{f_{NC}^*} / \partial S = 0$ can be obtained, and the quality efforts efficiency achieves the maximum $\overline{f_{NC(max)}^*}$ at the moment. When $S \in (S^-, S^+)$, the inequality $\partial \overline{f_{NC}^*} / \partial S < 0$ can be obtained, but the quality efforts efficiency decreases at a faster pace due to the reason that the food companies have the speculative mentality during the inception phase, which relies on the insurance companies' compensation or the government's subsidies instead of carrying out quality efforts to fill up the loss. When it reduces to the lowest point, namely, the turning point E , they will consider increasing the quality efforts investment under the influence of the dual pressures which are from the decreasing of the quality efforts efficiency and the increasing of the probability of bankruptcy crisis to be faced by food companies. The quality efforts efficiency will not stop decreasing for increasing the quality efforts investment, but the amplitude of the decrease will be smaller and smaller due to the inertia action. When $S = S^+$, the equation $\partial \overline{f_{NC}^*} / \partial S = 0$ can be obtained, and the quality efforts efficiency achieves the minimum $\overline{f_{NC(min)}^*}$ at the moment. When $S \in (S^+, +\infty)$, the inequality $\partial \overline{f_{NC}^*} / \partial S > 0$, $\partial^2 \overline{f_{NC}^*} / \partial S^2 > 0$ can be obtained; thus $\overline{f_{NC}^*}$ is directly proportional to S ; $\Delta \overline{f_{NC}^*}$ is increasing with the increase of S .

FIGURE 2: Relations between $\partial \overline{f_{NC}^*} / \partial S$, $\overline{f_{NC}^*}$, and S . FIGURE 3: Relations between $\partial \overline{f_{NC}^*} / \partial S$, $\overline{f_{NC}^*}$, and S in the conditions of three kinds of cooperation modalities.

The proving process which is under the situation of noncooperation is the same as that under the situation of semicooperation and cooperation. Only the curve gradient and the intersection point range of the abscissa are different under the three kinds of cooperation modalities, as shown in Figure 3. It can be seen from Figure 3 that S which the maximum value of the quality efforts efficiency corresponds to when the enterprise A is cooperative with enterprise B is less than that under the situation of noncooperation; namely, cooperative enterprises are more inclined to accommodate the smaller S . Therefore, the larger value of the quality efforts efficiency can be obtained if the enterprises A and B are cooperative when S is relatively small; conversely, the larger value of the quality efforts efficiency can also be obtained if the enterprises are uncooperative when S is relatively large. Meanwhile, Figure 3(b) shows that the great fluctuation in the quality efforts efficiency of the food supply chain will be caused by the small ΔS under the situation of cooperation. And even if the large ΔS cannot give rise to the great

fluctuation in the quality efforts efficiency under the situation of noncooperation, the sensitivity coefficient of the quality efforts efficiency to S is the highest in the case of cooperation and is the lowest in the case of noncooperation. Therefore, Proposition 19 has been demonstrated to be correct.

2.2.4. The Profits of the Food Supply Chain under the Different Cooperation Situations. Plug the above calculational results into the profit functions, and the profit functions of enterprises under the different cooperation situations can be obtained, as follows.

Noncooperation:

$$L_{ANC}^* = \left(\frac{8n^2}{a} - 2nN_A^2 S^2 \right) \cdot \frac{[N - a(c_A + c_B + N_A S + N_B S)]^2}{[8n - aS^2(N_B^2 + 2N_A^2)]^2},$$

$$\begin{aligned}
L_{\text{BNC}}^* &= \left(\frac{4n^2}{a} - \frac{1}{2}nN_B^2S^2 \right) \\
&\cdot \frac{[N - a(c_A + c_B + N_AS + N_BS)]^2}{[8n - aS^2(N_B^2 + 2N_A^2)]^2}, \\
L_{\text{NC}}^* &= \left[\frac{12n^2}{a} - \frac{1}{2}nS^2(4N_A^2 + N_B^2) \right] \\
&\cdot \frac{[N - a(c_A + c_B + N_AS + N_BS)]^2}{[8n - aS^2(N_B^2 + 2N_A^2)]^2}.
\end{aligned} \tag{15}$$

Semicooperation:

$$\begin{aligned}
L_{\text{ABC}}^* &= \left(\frac{8n^2}{a} - \frac{9}{2}nN_A^2S^2 \right) \\
&\cdot \frac{[N - a(c_A + c_B + N_AS + N_BS)]^2}{[8n - 3aS^2(N_B^2 + N_A^2)]^2}, \\
L_{\text{BBC}}^* &= \left(\frac{4n^2}{a} - \frac{9}{2}nN_B^2S^2 \right) \\
&\cdot \frac{[N - a(c_A + c_B + N_AS + N_BS)]^2}{[8n - 3aS^2(N_B^2 + N_A^2)]^2}, \\
L_{\text{BC}}^* &= \left[\frac{12n^2}{a} - \frac{9}{2}nS^2(N_A^2 + N_B^2) \right] \\
&\cdot \frac{[N - a(c_A + c_B + N_AS + N_BS)]^2}{[8n - 3aS^2(N_A^2 + N_B^2)]^2}.
\end{aligned} \tag{16}$$

Cooperation:

$$\begin{aligned}
L_{\text{HC}}^* &= \left[\frac{n^2}{a} - \frac{1}{2}nS^2(N_A^2 + N_B^2) \right] \\
&\cdot \frac{[N - a(c_A + c_B + N_AS + N_BS)]^2}{[2n - aS^2(N_A^2 + N_B^2)]^2}.
\end{aligned} \tag{17}$$

Proposition 20. *The higher the extent of cooperation in the quality and safety between the upstream and downstream enterprises, the higher the profits of the whole food supply chain that can be achieved. Therefore, one should strengthen cooperation between the upstream and downstream enterprises in the process of carrying out quality efforts.*

Demonstration. It can be seen from the inequality $L_{\text{BBC}}^* > 0$ that $4n^2/a - (9/2)nN_B^2S^2 > 0$ under the situation of semicooperation. Meanwhile the inequality $4n - 3aS^2(N_A^2 + N_B^2) > 0$ and $n - aS^2(N_A^2 + N_B^2) > 0$ can be obtained through comparing the profit function values under the different cooperation situations. Therefore, the inequality $L_{\text{BC}}^* > L_{\text{NC}}^*$ and $L_{\text{HC}}^* > L_{\text{BC}}^*$ can be obtained; namely, $L_{\text{HC}}^* > L_{\text{BC}}^* > L_{\text{NC}}^*$. Proposition 20 has been demonstrated to be correct.

2.2.5. The Social Welfare Comparison without Considering the Externality under Different Cooperation Situations. Regardless of the externality, (the sum of the producer surplus and consumer surplus is social welfare regardless of the externality) the social welfare is that

$$\begin{aligned}
W &= \int_0^{Q^*} \left(\frac{N-x}{a} - c_i \right) dx - \frac{1}{2}nf^2 \\
&= \left(\frac{N}{a} - c_i \right) Q^* - \frac{Q^{*2}}{2a} - \frac{1}{2}nf^2.
\end{aligned} \tag{18}$$

Bring the simplified demand functions into (18), and then the simplified social welfare expressions under the different cooperation situations can be obtained, as follows:

$$\begin{aligned}
\overline{W}_{\text{NC}}^* &= \frac{2n(N-2S)}{8n-3S^2} \left[N - \frac{n(N-2S)}{8n-3S^2} - \frac{9}{4} \frac{S^2(N-2S)}{8n-3S^2} \right], \\
\overline{W}_{\text{BC}}^* &= \frac{2n(N-2S)}{8n-6S^2} \left[N - \frac{n(N-2S)}{8n-6S^2} - \frac{9S^2(N-2S)}{8n-6S^2} \right], \\
\overline{W}_{\text{HC}}^* &= \frac{n(N-2S)}{2n-2S^2} \left[N - \frac{1}{2} \frac{n(N-2S)}{2n-2S^2} - \frac{2S^2(N-2S)}{2n-2S^2} \right].
\end{aligned} \tag{19}$$

Proposition 21. *Social welfare will increase with the increase of the extent of cooperation on the quality and safety between the upstream and downstream enterprises without considering the externality influence caused by food safety incidents.*

Demonstration. Due to $\overline{W}_{\text{BC}}^* - \overline{W}_{\text{NC}}^* > 0$, $4((9/2)S^3 - (21/4)NS^2) < 18S^3 - 15NS^2$, $8n-6S^2 < 8n-3S^2$; thus the inequality $\overline{W}_{\text{HC}}^* - \overline{W}_{\text{BC}}^* > 0$ can be obtained; namely, $\overline{W}_{\text{HC}}^* > \overline{W}_{\text{BC}}^* > \overline{W}_{\text{NC}}^*$. Therefore, Proposition 21 has been demonstrated to be correct.

3. The Analysis of the Factors Which Influence the Enterprises' Collaboration Strategy for the Quality and Safety

The close cooperation between all of the links (the node enterprises) in the food supply chain can be realized through establishing the cooperation, incentive, and supervision mechanism. However, the macro environment (including the related governmental policies and laws that continue to move forward in a timely fashion and the general public (the consumers' consumption habit, the consumption concept, consumption evaluation, consumption quality migration, news media exposure, etc.)) and the micro environment (company's earnings in future, etc.) will also be the important basis for companies' decision-making in the process of cooperation between the upstream and downstream enterprises.

TABLE 1: The strategic payoff matrix of the game.

Enterprise A	Enterprise B	
	$B_1(q)$	$B_2(1-q)$
$A_1(p)$	$q_C(c_1 - k_1) + g + v$ $q_C(c_2 - k_2) + g + v$	$q_C(c_1 - k_1) + g + v$ $l_2 - s - \delta[\eta\phi h + \eta(1-\phi)\varphi m + (1-\eta)m] - \Delta k$
$A_2(1-p)$	$l_1 - s - \delta[\eta\phi h + \eta(1-\phi)\varphi m + (1-\eta)m] - \Delta k$	$q_C(c_2 - k_2) + g + v$ $-\delta[\eta\phi h + \eta(1-\phi)\varphi m + (1-\eta)m] - \Delta k$ $-\delta[\eta\phi h + \eta(1-\phi)\varphi m + (1-\eta)m] - \Delta k$

Note. p, q are the proportion of the individuals in two game groups who choose the strategies A_1 and A_2 .

The above model hypothesis does not take into account the macro environment and the micro environment variables.

Therefore, analyzing the enterprises' behavioral characteristics in the process of cooperation and the factors which influence enterprises' collaboration strategy for the quality efforts is new expansion of researches on the enterprises' collaboration strategy for the quality and safety in the conventional sense through applying evolutionary economics approach and introducing the macro and micro environment variables to construct evolutionary game model.

3.1. The Establishment of the Model

Assumption 1. The benefits that the unit quality efforts can bring for the enterprises A and B, respectively, are c_1, c_2 . The cost of per unit quality efforts that enterprises A and B should pay for, respectively, is k_1, k_2 . The output of both enterprises is q_C . The earnings of enterprise A that does not carry out quality efforts are l_1 when the enterprise B carries out quality efforts; the market demand will increase due to the quality efforts of enterprise B at the moment, and the benefits of hitchhiking of the enterprise A can be realized when it does not increase input. The earnings of enterprise B that does not carry out quality efforts are l_2 when the enterprise A carries out quality efforts; the market demand will increase due to the quality efforts of enterprise A at the moment, and the benefits of hitchhiking of the enterprise B can be realized when it does not increase input.

Assumption 2. The government will grant subsidies which are g to the enterprises that carry out quality efforts. The supervisory departments will strictly monitor and punish the enterprises that do not carry out quality efforts in order to hurt their chances of hitchhiking, and the penalty is m ; the supervision efficiency is δ . Consumers expose the enterprises' hitchhiking behavior through their own evaluation mechanism; the enterprises' beneficial losses (e.g., reputation, integrity) caused by it are s ($s < \min(l_1, l_2)$). But there may exist the power rent-seeking behavior in the supervisory process; the probability of it is η ; therefore, the enterprises that do not carry out quality efforts can avoid the penalty through offering bribes (the probability is ϕ ; the bribes are h) to the supervisory departments. The penalty for the supervisory departments which will abuse their authority charge illegally is φm ($\varphi > 1$) if they do not bribe them (the probability is $1 - \phi$). Meanwhile, consumers have strong cognitive ability about food quality and safety; they are able to identify different quality of products and are willing to pay

the price discrimination and their demands will increase because of the enterprises' quality efforts strategy; then the benefits that can be brought are v . The general public's supervision, including news media and consumers, and the action to expose the supervisory departments' laziness behavior, the collusion behavior between local governments and firms, the power rent-seeking behavior, and so forth can increase the defensive costs of the potential enterprises that do not carry out quality efforts, which are Δk .

This paper constructs the strategic payoff matrix of the game between enterprise A group and enterprise B group based on the above assumptions, as shown in Table 1.

If the adaptability of adopting a strategy is higher than the average adaptability of the group, then the probability of adopting the strategy will increase gradually as time t goes on [32] according to the Malthusian dynamic equations. The replication dynamic differential equations of the strategy interaction between enterprises A and B evolving with time can be obtained based on the methods that the literatures [33, 34] proposed, as follows:

$$\begin{aligned} \frac{dp}{dt} &= p(1-p) \{q(s-l_1) + q_C(c_1-k_1) + g + v \\ &\quad + \delta[\eta\phi h + \eta(1-\phi)\varphi m + (1-\eta)m] + \Delta k\}, \\ \frac{dq}{dt} &= q(1-q) \{p(s-l_2) + q_C(c_2-k_2) + g + v \\ &\quad + \delta[\eta\phi h + \eta(1-\phi)\varphi m + (1-\eta)m] + \Delta k\}. \end{aligned} \quad (20)$$

Let $dp/dt = 0, dq/dt = 0$; we can draw the evolutionary phase diagram of the game (Figure 9(a)) and work out the equilibrium points of the system equations that are $(0, 0)$, $(0, 1)$, $(1, 0)$, $(1, 1)$, (p^*, q^*) when $\eta < \min\{(l_2 - s - q_C(c_2 - k_2) - g - v - \Delta k - \delta m) / \delta[\phi h + (1 - \phi)\varphi m - m], (l_1 - s - q_C(c_1 - k_1) - g - v - \Delta k - \delta m) / \delta[\phi h + (1 - \phi)\varphi m - m]\}$. $N(0, 1)$, $W(1, 0)$ are instability points, $G(p^*, q^*)$ is the saddle point, and $O(0, 0)$, $M(1, 1)$ are evolutionary stable strategy (ESS) according to the matrix *Jacobian* characteristic value theorem. It can be seen from Figure 9(a) that regime I is the probability of the system converging to the locked equilibrium status model (A_2, B_2) and regime II is the probability of the system converging to the ideal equilibrium status model (A_1, B_1) .

3.2. The Analysis of the Macro Factors Which Influence the Cooperation Strategy. Considering the complexity of the computation on the game equilibrium results, this paper analyzes the mechanism that the change of macro-environmental

FIGURE 4: The influence of the government's positive stimulus on the cooperation strategy.

FIGURE 5: The influence of the government's supervision efficiency on the cooperation strategy.

variables influences the evolution of the cooperation strategy behavior with the help of *Matlab* to conduct the numerical example simulations. With reference to the related literatures [35–37], the following parameters are set to $c_1 = 3$, $c_2 = 2$, $k_1 = 2$, $k_2 = 1$, $q_C = 2$, $l_1 = 9.5$, $l_2 = 9$, $g = 1$, $m = 2$, $\delta = 0.1$, $s = 0.5$, $\eta = 0.5$, $\phi = 0.2$, $h = 1.5$, $\varphi = 1.5$, $\nu = 1$, and $\Delta k = 1$. The results of numerical simulation experiments are shown in Figures 4–8.

It can be seen from the numerical simulation results that the government's positive stimulus, efficient regulation, and

appropriate punishment, the consumers' positive guidance, and the news media's efficient disclosure mechanism can encourage the enterprises to increase investment in quality efforts and strengthen the enterprises' cooperation strategy for the quality efforts.

Through comparing Figure 6(a) with Figures 6(b) and 6(c), we can find an interesting phenomenon that the probability of the rail line converging to the ideal equilibrium status increases significantly and even can be completely evolved to the ideal equilibrium status model with the increase of

FIGURE 6: The influence of the punishing dynamics of government on the cooperation strategy.

the punishing dynamics, but it will increase the uncertainty of the evolutionary path when the punishing dynamics are beyond the limits. It can be seen from Figure 6(c) that the rail line at $p_0 = 0.5$ boundaries converges to two modes and the probability of the rail line converging to the locked equilibrium status model is higher. It seems that this is in contradiction with what we have done in reality that we should increase the punishing dynamics for the quality inaction actions if we want to boost enterprises' cooperation incentive. The explanation and the demonstration for this point can be described as the follows:

$$\begin{aligned}
 l_2 - s - \delta\eta\phi h - \delta\eta(1-\phi)\phi m - \delta(1-\eta)m - \Delta k \\
 - q_C(c_2 - k_2) - g - v > 0.
 \end{aligned}
 \quad (21)$$

Take the derivative of the inequality's left side with respect to m , and the following inequality can be obtained, as follows:

$$-\delta\eta(1-\phi)\phi - \delta(1-\eta) < 0. \quad (22)$$

It indicates that the income difference that companies adhere to carry out quality efforts changes in the opposite direction with the change of m . Therefore, appropriate punishment will be conducive to jumping out of the locked status, and excessive punishment can easily lead to the government departments slacking off more and choosing the strategy that does not supervise enterprises.

3.3. The Analysis of the Micro Factors Which Influence the Cooperation Strategy. Suppose the opportunity income's loss that is caused due to the reason that the enterprises A and B

FIGURE 7: The influence of the consumers' positive guidance on the cooperation strategy.

FIGURE 8: The influence of the news media's disclosure mechanism on the cooperation strategy.

do not choose the cooperation strategy is l_A, l_B . The discount factor of the enterprise future earnings (it can reflect the degree of mutual trust between the enterprises and enterprises concern about the extra income they can receive from the future cooperation) is $\varepsilon_A, \varepsilon_B$. Meanwhile, the replication dynamic differential equations of the strategy interaction between enterprises A and B evolving with time can be obtained by introducing the future earnings factor into the above model, as follows:

$$\frac{dp}{dt} = p(1-p) \{q(s-l_1) + q_C(c_1-k_1) + g + v + \delta[\eta\phi h + \eta(1-\phi)\phi m + (1-\eta)m] + \Delta k$$

$$+ l_A \varepsilon_A\},$$

$$\begin{aligned} \frac{dq}{dt} = & q(1-q) \{p(s-l_2) + q_C(c_2-k_2) + g + v \\ & + \delta[\eta\phi h + \eta(1-\phi)\phi m + (1-\eta)m] + \Delta k \\ & + l_B \varepsilon_B\}. \end{aligned}$$

(23)

We can draw the evolutionary phase diagram of the game (Figure 9(b)) and work out the equilibrium points of the system equations that are $(0, 0)$, $(0, 1)$, $(1, 0)$, and $(1, 1)$ based

FIGURE 9: The replication dynamic evolutionary phase diagram of the strategy interaction between enterprises.

on the equations $dp/dt = 0$, $dq/dt = 0$ when $l_A \varepsilon_A > l_1 - s - \{q_C(c_1 - k_1) + g + v + \delta[\eta\phi h + \eta(1 - \phi)\varphi m + (1 - \eta)m] + \Delta k\}$, $l_B \varepsilon_B > l_2 - s - \{q_C(c_2 - k_2) + g + v + \delta[\eta\phi h + \eta(1 - \phi)\varphi m + (1 - \eta)m] + \Delta k\}$. According to the matrix *Jacobian* characteristic value theorem, $(0, 0)$, $(0, 1)$, and $(1, 0)$ are instability points; $(1, 1)$ is evolutionary stable strategy (ESS). Figure 9(b) indicates that the system will converge to the ideal equilibrium status model (A_1, B_1) when it starts from any initial state. The proposition is correct obviously.

Therefore, increasing the discount value of the enterprise future earnings can encourage the enterprises to cooperate in quality and safety. It indicates that enterprises *A* and *B* should enhance mutual trust, establish long-term strategic cooperation partnership, and work hard for creating excellent cooperation environment for the quality and safety in the food supply chain.

4. Conclusions

This paper mainly discusses two problems: firstly, the cooperation strategy for the quality and safety between the upstream and downstream enterprises of the food supply chain and, secondly, the macro and micro factors that influence the collaboration strategy for the quality and safety. The research results as follows:

- (1) The food supply chain form that cooperates in both the quality and safety and pricing can achieve the high-quality efforts efficiency and obtain high profits simultaneously in the conditions of three kinds of cooperation modalities, which are noncooperation, semicooperation, and cooperation.
- (2) The interaction between the loss that the average quality and safety events of per unit food caused each time and the quality efforts marginal cost can influence

the upstream and downstream enterprises' quality efforts effectiveness. The loss that the food quality and safety events caused has a vital impact on the enterprises' quality efforts efficiency. There is a negative correlation between the quality efforts efficiency and the loss when the degree of quality efforts is higher, and instead there is a positive correlation between them.

- (3) The direct consequence of enterprises in pursuit of maximum profit is that they will reduce the total investment in quality efforts. But increasing the discount value of the enterprise future earnings can encourage the enterprises to cooperate on quality and safety and enhance mutual trust, establish long-term strategic cooperation partnership, and work hard for creating excellent cooperation environment for the quality and safety in the food supply chain.

Meanwhile, the macro environment will be the important basis for the enterprises' decision-making on collaboration strategy. The government should establish incentive and supervision mechanism, and they also should increase the compensation intensity for companies that carry out the quality and safety efforts. The supervisory departments should strengthen supervision on enterprises that do not carry out the quality and safety efforts, improve the supervision efficiency, and appropriately punish them. The news media should disclose timely the enterprises' behavior of not doing more to carry out quality efforts and hurt their chances of hitchhiking. However, excessive punishment can easily lead to the supervisory departments slacking off more and choosing the strategy that does not supervise enterprises. Therefore, the government should simultaneously strengthen supervision and increase the punishing dynamics for the supervisory departments' behavior, including the laziness behavior, the inaction behavior, and the power rent-seeking behavior.

The signal transmission which is about the quality and safety of the food supply chain can realize the food quality and safety information in two-way communication between enterprises and consumers, and it is beneficial to transform the food quality and safety's credence goods features into search goods features. Consumers can accurately distinguish the level of food quality and safety and realize the separation between high-quality food production enterprises and low-quality food production enterprises; it also can encourage enterprises that do not carry out the quality and safety efforts to increase investment in quality efforts and ultimately achieve the goal of improving the level of food quality and safety progressively due to the reason that low-quality food production enterprises cannot imitate the strong signal sent from high-quality food production enterprises. Consumers are willing to pay the price discrimination for the food whose level of quality and safety is high. The companies' profits will increase due to the increased consumer demands, thus further promoting enterprises to increase investment in quality efforts. However, to explore how to improve the signal transmission mechanism and the path that can ensure the efficient transfer of the signal to consumers is worth further analysis.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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