ESTABLISHING FOOD TRACEABILITY SYSTEM BASED ON GAME THEORY

From the Perspective of Retailers

Wei Jin-shi and Lan Hong-jie
School of Economics and Management, Beijing Jiaotong University, Haidian District, 100044 Beijing, China

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Abstract: Retail terminal is a weak link of the whole food supply chain in establishing the food traceability system, and also a key link in realizing traceability food value. This paper firstly analyzes the influence factors of retails adopting food traceability technology, then makes a game model to analyze three situations: non-government subsidy; the same government subsidy for adopting the traceability technology and higher subsidy for who adopts the system first. According to the analysis, the conclusion is drawn: it is unrealistic to ask all of retails to adopt food traceability technology; corresponding policy should be made to inspire a part of retails adopting the system first.

1 INTRODUCTION

The traceability system was first used in product recall system of industrial product such as automobiles or planes, and later was applied to food safety control, as food issues become increasingly important. To the relatively new food traceability system, many domestic and foreign scholars have carried on massive basic researches.

The European commission (EC178/2002) defines food traceability as traceability or retroactive ability to food, feed, edible animals and all matter that might be composition of food or feed, in each link of production, processing and sales. International food Codex Alimentary Commission (CAC) and International Organization for Standardization (ISO) defines traceability as the ability to track the history, use or position of commodities or behaviour, through the registered identification number. Fang Yan et al. (2005) define food traceability system as continuity security system of information flow on each food supply stage.

To the features of traceability system, domestic and foreign scholars have also done a lot of research work. Danish scholar Moe T. (1998) thinks the traceability system consists of products and production activities. According to the scope of implementation, it can be divided into the traceability system between enterprises and the traceability system within enterprise. American scholar Elise Golan (2004) thinks traceability system refers to the record system of tracking a product or product characteristics in entire process or supply chain system, and set three standards to measure the traceability system, according to the difference of traceability system characteristics: breadth, depth, precision. Shi Yan-tao (2006) thinks food traceability product also has positive externality and network economy features.

At present, scholars' researches on the traceability system are mainly aimed at the whole supply chain or production and processing links on supply chain, but there is few researches aimed at the retail enterprises on the end of supply chain. Chen Hong-hua etc(2009) analyzes the retailers' role and status, from the angle of supply chain, and puts forward related suggestions of retailers' role and the measures should be taken to establish China's agricultural product traceability system. On this basis, this paper studies the factors that influence retail enterprises on traceability system implement, and establishes game model to quantitatively analyze the timeliness of the traceability system.

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2 THE PRESENT SITUATION OF RETAILERS ADOPTING THE FOOD TRACEABILITY TECHNOLOGY

Retail enterprises are at the end of the entire supply chain, contacting with the production, processing and consumers, and are main route and channel for consumers to find traceability information of products, playing an important role as a bridge in entire food traceability system. In addition, retail enterprises take a increasingly dominant position in the entire supply chain, and play a more and more predominant role in the supply chain. Therefore, retail enterprises implementing the traceability technology could further promote the establishment of the whole supply chain food traceability system.

2.1 Analyzing the Present Situation of Retailers adopting the Food Traceability Technology in Our Country

At present, a few retail enterprises have equipped with food traceability information query system, but overall implementation condition is not ideal. During Beijing food logistics investigation process, it is found that only a few large supermarkets fixed food traceability information query system, and those equipments are often closed, in order that consumers cannot query. But there is some difference between truly finding the information terminal system provided in the inquiry and the whole process information query mentioned in the traceability system. Information quantity is less in the former, and it doesn't provide complete information traceability really.

2.2 Analyzing the Influence Factors of Retailers adopting the Food Traceability Technology

Yang Qiu-hong (2008) thinks that factors influencing cost of enterprises to establish the traceability system include: the depth, width and accuracy of the traceability system, the cooperation relationship between the enterprise and the upstream and downstream departments, enterprise production process, technological factors. Factors influencing profit of enterprises to establish the traceability technology include mainly consumers' willingness to pay for the traceability food, probability of food safety issues, the loss the food safety issues bring to enterprise, the improvement of supply chain efficiency after the establishment of the traceability system, product differentiation and branding. The author thinks retail enterprises whether to implement the traceability technology will also influenced by government support strength, competition between colleague enterprises.

From the perspective of cost and profit, internal game will happen in retail enterprise when deciding whether to implement the traceability technology. Overall, with the passage of time, implementing subject of the traceability technology has a deep knowledge of the system research, and accordingly the management and technology level enhances unceasingly. Therefore, the later the enterprise implement the traceability technology, the less cost they burden. On the other hand, with the passage of time, the knowledge of the consumer to food traceability technology increasing, and their willingness to pay for the traceability technology increases, too. Therefore, the earlier the enterprise implements the traceability system, the more profit they obtain.

From the perspective of competition, balanced game will happen between retail enterprises when deciding whether to implement the traceability system. The enterprises taking the lead to use the traceability system, will plunder the parts of the market competition, but should burden higher cost, and also consider that competitor will regain market share after implementing the traceability technology; the enterprises later using the traceability technology will enjoy low cost but should undertake the risk of losing market.

Therefore, when implementing the traceability technology，retail enterprises should balance cost and benefit, and the competition between the colleagues, in order to attain their total profit maximization.

3 ANALYZING THE TIMING OF THE TRACEABILITY TECHNOLOGY FOR RETAILERS BY GAME MODEL

3.1 Basic Hypotheses

Supposing that there exist only two retailers in a certain region and they are A and B. In order to facilitate the calculation and without loss of generality, let's suppose that the market share of this region is divided equally by these two retailers. And retailer A adopts the traceability technology first and B later. If A makes the adoption at time t_1 and B at time, it is apparent that $t_1 \le t_2$ .The consumers' demand Q for food in the short term is constant. Then the sales volume of traceability products can be β *Q, in which β is the consumers' preference degree to buy traceability products. We can get β by $\beta = 1 - e^{-kt}$ where k is a constant. It means that consumers' preference degree improves with increasing time. $\upsilon(\mathrm{t})$ is the benefit rate at time t and S= (s_1, s_2) means the adoption strategies of A and B, in which A adopts strategy s_1 and B adopts s_2 .When s_i =1 it means that the traceability technology is adopted, but when s_i =0, the system is not adopted. Then the total benefit rate of A and B when they each makes different strategies can be shown as below:

$$v(t) = \begin{cases} \frac{1}{2}\mathrm{Qr} & (s_1, s_2) = (1,1) \\ \frac{1}{2}Q(1+\beta)r & (s_1, s_2) = (1,0) \\ \frac{1}{2}Q(1-\beta)r & (s_1, s_2) = (0,1) \\ \frac{1}{2}\mathrm{Qr} & (s_1, s_2) = (0,0) \end{cases}$$

Where r is the average profit of retail products.

The adoption cost of the traceability can be calculated by $c(t) = ae^{-kt}$ and it means that with time increasing, the management and technology level of the traceability technology will be gradually improved so that the adoption cost for retailers will become lower and lower. The discount rate is α and $\mathrm{Z(t)}$ is the expected benefit increase after the adoption of the system.

3.2 Model Analysis

According to the actual situation, this paper has mainly considered three situations: non-government subsidy; the same government subsidy for adopting the traceability technology; higher subsidy for who adopts the system first.

3.2.1 The Non-government Subsidy Situation

Without the adoption of the traceability technology the benefit rate per unit of time for A is $\frac{1}{2}\mathrm{Qr}$; when A adopt the system before B, it is $\frac{1}{2}Q(1+\beta)r$; if A adopt the system after B, it becomes $\frac{1}{2}\mathrm{Qr}$. Therefore, the expected benefit increase for A is:

$$\mathrm{Z}(\mathrm{t}_1) = \int_{t_1}^{t_2} \frac{1}{2}Q(1+\beta)re^{-\alpha t}dt + \int_{t_2}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt - \int_{t_1}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt - \mathrm{c}(\mathrm{t}_1)e^{-\alpha t_1} \tag{1}$$

Calculate the first derivative of $\mathrm{Z}(\mathrm{t}_1)$ and we can get:

$$\mathrm{t}_1^* = -\frac{1}{k}\ln\left[\frac{\mathrm{Qr}}{\mathrm{Qr} + 2\mathrm{a}(\alpha + \mathrm{k})}\right]$$

When $t_1 = t_1^*$, A can get the maximum benefit.

When A has adopted the system, if B gives up adopting it $v(\mathrm{t}_2) = \frac{1}{2}Q(1-\beta)r$; if B also chooses to adopt the system, $v(\mathrm{t}_2) = \frac{1}{2}\mathrm{Qr}$. Therefore, the expected benefit increase for B is:

$$\mathrm{Z}(\mathrm{t}_2) = \int_{t_2}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt - \int_{t_2}^{+\infty}\frac{1}{2}Q(1-\beta)re^{-\alpha t}dt - c(t_2)e^{-\alpha t_2} \tag{2}$$

Calculate the first derivative of $\mathrm{Z}(\mathrm{t}_2)$ and we can get:

$$\mathrm{t}_2^* = -\frac{1}{k}\ln\left[\frac{\mathrm{Qr}}{\mathrm{Qr} + 2\mathrm{a}(\alpha + \mathrm{k})}\right]$$

When $t_2 = t_2^*$, B can get the maximum benefit.

That is to say, we had better to make $t_1^* = t_2^*$. Put $t_1^* = t_2^* = -\frac{1}{k}\ln\left[\frac{\mathrm{Qr}}{\mathrm{Qr}+2\mathrm{a}(\alpha+\mathrm{k})}\right]$ in (1) and (2) we can get:

$$\mathrm{Z}(\mathrm{t}_1^*) = -a\left[\frac{Qr}{Qr + 2a(\alpha + k)}\right]^{1+\frac{\alpha}{k}} < 0 \tag{3}$$

$$\mathrm{Z}(\mathrm{t}_2^*) = \frac{k(Qr + 2a(\alpha + k))}{2a(\alpha + k)} * \left[\frac{Qr}{Qr + 2a(\alpha + k)}\right]^{1+\frac{\alpha}{k}} > 0 \tag{4}$$

It can be seen from (3) and (4) that: when A has adopted the system first, B can get a higher benefit if it also adopts the system than if not, so the best strategy for B is that once A adopts the system, B should too; if B chooses to adopt the system right after A's adoption, A's benefit will decrease, so the best strategy for A is not to adopt it.

From the above the conclusion can be drawn that without the government subsidy, retailer A and retailer B will not adopt the traceability technology.

3.2.2 The Same Government Subsidy Situation

Supposing that government provides the same subsidy G to those who adopt the traceability technology no matter who adopts it first, then the expected benefit increase for retailer A is:

$$Z(t_1)=\int_{t_1}^{t_2}\frac{1}{2}Q(1+\beta)re^{-\alpha t}dt+\int_{t_2}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt-\int_{t_1}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt-c(t_1)e^{-\alpha t_1}+Ge^{-\alpha t_1} \tag{5}$$

Calculate the first derivative of $Z(t_1)$ and we can get:

$$t_1^{\#}=-\frac{1}{k}\ln\left[\frac{Qr+2\alpha G}{Qr+2a(\alpha+k)}\right]$$

The expected benefit increase for retailer B is:

$$Z(t_2)=\int_{t_2}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt-\int_{t_2}^{+\infty}\frac{1}{2}Q(1-\beta)re^{-\alpha t}dt-c(t_2)e^{-\alpha t_2}+Ge^{-\alpha t_2} \tag{6}$$

Calculate the first derivative of $Z(t_2)$ and we can get:

$$t_2^{\#}=-\frac{1}{k}\ln\left[\frac{Qr+2\alpha G}{Qr+2a(\alpha+k)}\right]$$

Put $t_1^{\#}=t_2^{\#}=-\frac{1}{k}\ln\left[\frac{Qr+2\alpha G}{Qr+2a(\alpha+k)}\right]$ in (5) and (6) we can get:

$$Z(t_1^{\#})=G\left[\frac{Qr+2\alpha G}{Qr+2a(\alpha+k)}\right]^{\frac{\alpha}{k}}-a\left[\frac{Qr+2\alpha G}{Qr+2a(\alpha+k)}\right]^{1+\frac{\alpha}{k}} \tag{7}$$

$$Z(t_2^{\#})=\left[\frac{Qr+2\alpha G}{Qr+2a(\alpha+k)}\right]^{1+\frac{\alpha}{k}}+\frac{k(Qr+2a(\alpha+k))}{2a(\alpha+k)}\left[\frac{Qr+2\alpha G}{Qr+2a(\alpha+k)}\right]^{1+\frac{\alpha}{k}} \tag{8}$$

From (7) and (8) the following conclusions can be got. For retailer A, when $Z(t_1^{\#})>0$ i.e. $G>\frac{Qar}{Qr+2ak}$, the benefit will get increased if it adopts the system and it should adopt the system at time $t_1^{\#}$; when $G<\frac{Qar}{Qr+2ak}$, the benefit will get decreased if it adopts the system so it should give up the adoption. While for retailer B, since $Z(t_2^{\#})>0$, if A has adopted the system first, the best strategy for B is to adopt the system, too.

From the above the conclusion can be drawn that if government provides the same subsidy to those who adopts the traceability technology: when $Z(t_1^{\#})>0$, A and B will adopt the system at the same time; when $Z(t_1^{\#})<0$, neither A nor B will adopt the system.

3.2.3 The Discrepant Government Subsidy Situation

Supposing that government provides subsidy G_1 to who adopts the traceability technology first and G_2 to who adopts it later and $G_1>G_2$. Then the expected benefit increase for retailer A is:

$$Z(t_1)=\int_{t_1}^{t_2}\frac{1}{2}Q(1+\beta)re^{-\alpha t}dt+\int_{t_2}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt-\int_{t_1}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt-c(t_1)e^{-\alpha t_1}+G_1e^{-\alpha t_1}$$

Upon calculation, when $Z(t_1)$ gets the maximum value $Z(t_1^{\otimes})$, $t_1^{\otimes}=-\frac{1}{k}\ln\left[\frac{Qr+2\alpha G_1}{Qr+2a(\alpha+k)}\right]$. The expected benefit increase for retailer B is:

$$Z(t_2)=\int_{t_1}^{t_2}\frac{1}{2}Q(1-\beta)re^{-\alpha t}dt+\int_{t_2}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt-\int_{t_1}^{+\infty}\frac{1}{2}Qre^{-\alpha t}dt-c(t_2)e^{-\alpha t_2}+G_2e^{-\alpha t_2}$$

Upon calculation, when $Z(t_2)$ gets the maximum value $Z(t_2^{\otimes})$,

$$t_2^{\otimes}=-\frac{1}{k}\ln\left[\frac{Qr+2\alpha G_2}{Qr+2a(\alpha+k)}\right]$$

When $Z(t_1^{\otimes})>0$: if $Z(t_1^{\otimes})>Z(t_2^{\otimes})$, A can get a higher benefit, so both retailers want to adopt the traceability technology at time $t_1^{\otimes}$; if $Z(t_1^{\otimes})<Z(t_2^{\otimes})$, A can get a certain benefit but B can get more, so both retailers want to be the one who make the adoption later and in this situation the differentiation of government subsidy has lost its meaning.

When $Z(t_1^{\otimes})<0$, A will get a decreased benefit so no retailer will adopt the traceability technology.

Above all, only when $Z(t_1^{\otimes}) > 0$ and $Z(t_1^{\otimes}) > Z(t_2^{\otimes})$, can the differentiation of government subsidy encourage retailers to adopt the traceability technology earlier. What's more, the relevant numeric area of G_1 and G_2 can be get from the above equations.

4 CONCLUSIONS

This paper has presented the current situation and effect factors of retailer's adoption of the traceability technology, and made the game model to analyze the timing of retailer's adoption of the traceability technology in three situations. Then, I reached the conclusions: retails will not implement traceability technology without subsidy; the measure of providing higher subsidy for who adopts the system first is superior to others in term of timing and government financial input.

In conclusion, it is rather unrealistic to ask all food retailers implement traceability technology. However, if the government departments take the measure of providing higher subsidy for who adopts the system first, then competition among retails would inspire other retailers to implement traceability technology earlier, and a good basic for food traceability standards would be set up.

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