Research on Repeated Game Between Food Enterprises and Government Regulators

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Abstract In view of China's frequent food safety incidents in recent years, this paper builds a repeated game model to study the interaction between food enterprises and government regulators, based on quantifying the returns of them. It designs the optimum of food enterprises product pass rate under the current discount rate and the existing relationship. The result shows that regulation has an important impact on product pass rate of food enterprises, and it has positive significance to maintain appropriate regulation for both sides.
Key words Food enterprises; Government regulators; Repeated game; Discount rate; Pass rate

1 Introduction

Food industry has become a pillar industry of national economy. But in recent years regulation work has been overwhelmed by frequent food safety incidents, which impair consumers' health, invade their rights and further disrepute the food industry. How to ensure food safety has become a hot issue in public.

Faced with this situation, big measures have been taken continuously in food safety field in the past year. On June 1, 2009, Food Safety Law was implemented. On February 6, 2010, the State Council set up Food Safety Committee consisting of 15 departments, commanded by vice-Premier Li Keqiang. This series of measures mark the country's great attention on food safety. However, there are so many links in food production and trade process. If there is something wrong with any link, a variety of safety problems may occur, which will affect people's life and health, disturb market order and even affect social stability.

Chinese and foreign scholars have different views in analyzing the relationship between food security and government regulation.

From the perspective of game theory, foreign scholars believe that it will result in information asymmetry between food producers and consumers because of the characteristics of food itself (Hirschauer, 1999, Mccluskey, 2000). Food safety regulatory policies are the results of game between domestic and foreign consumers, farmers, food manufacturers, food retailers, government, taxpayers and other interest groups. Food safety regulatory policies achieve a balance among different interests of different groups (Edward Glaeser, Andrei Shleifer, 2002).

Zhang Yunhua, Kong Xiangzhi, Yang Xiaoyan etc. (2004) analyze the strategic choices among food supply chain using a single game, repeated game and dynamic game with incomplete information respectively. Their analysis shows that people who are food supply chain actors in one-time market transactions will choose non-cooperation of opportunistic behavior because they want to maximize their own interests. But in the indefinite repeated game, the food chain actors will achieve a cooperative equilibrium. Therefore it achieves food supply security.

Zhang Sihai, Xu min and Wang Xifa (2006) extend the strategy selection in 2-person iterated prisoner dilemma. They design a computer competition based on game strategy. The experimental results show that TIT-FOR-TAT and ALWAYS_DEDECT are not always the best strategy, and the best strategy is closely correlated with repeated times and strategy distribution.

Liu Songxian and Li Yanbo (2006) study the game relationship which is not only conditioned but also associated with each other between government departments and food enterprises in the process of building food safety. They think it is possible to achieve food safety through regulatory departments, food enterprises and other areas work together to fulfill their corresponding responsibilities.

Wang Wenping, Dengyulin and Shan Haiyan (2007) quantify the returns of social relationships between core enterprises and accessorial enterprises. They discuss the influencing factors of constructing and keeping social relations between them and prove that constructing and keeping such social relations depend on the core enterprises expectation of the returns of social relations and the market price of accessorial enterprises.

Zhang Gongyi, Dong bingnan and Ding Jianxun (2008) establish the collusion game model of food safety regulation based on analysis of information asymmetry and excess profits from non-safe food production. They get the key factors affecting food safety, and make some recommendations.

This paper mainly focuses on discussing and solving the relationship between food enterprises and relevant government regulators in the issue of food safety.

2 A Game Model

Game theory mainly studies the interaction and mutual restriction of actions between individuals. This paper takes food enterprises and government regulators as the two parties of the game to study the effective regulatory mode of government as well as the positive interaction mode of both sides by analyzing the different returns when the two sides adopt different strategies.

It is a long and repeated process for government to regulate food enterprises. One side seeks to maximize the interests of whole society while the other party seeks to maximize individual interests. Both sides pursue their own goal respectively by mutual restrictions like tacit understanding and cooperation or retaliation and threat. It is a kind of two-person n-stage repeated game form.

The payoff matrix of this game is shown in Table 1.

Set the two sides of game as government regulators and food enterprises. Every action of the two sides is public information. Suppose government regulators have two alternative strategies: regulate and not regulate. Food enterprises also have two alternative strategies: produce qualified food and produce unqualified food. R stands for enterprises returns, *C* for fixed cost of enterprises, and suppose $R > C$. x is the probability of qualified food produced, or product pass rate. $C_1(x)$ is the additional cost food enterprises have to pay for producing qualified products, which increases with the increase of product pass rate and is strictly convex function of pass rate , that is $C_1^{'}(x) > 0$, $C_1^{''}(x) > 0$. Suppose the rate of change of marginal cost is a, you can define $C_1(x) = ax^2$. G is the punishment made by government regulators to food enterprises after unqualified products are discovered, and V is regulation cost, $V>0$.

Table 1 Payoff Matrix of the Game between Food Enterprises and Government regulators

		Government regulators			
		Regulate		Not Regulate	
Food Enterprises	Qualified x	$R-C-C_1(x),$	$-V$	$R-C-C_1(x),$	0
	Unqualified $1-x$	$-C-G,$	$-V$	$R-C,$	0

3 Model Analysis

3.1 Analysis of single-stage static game model

E_g is the expected returns of government regulators. It is $-V$ (regulation needs cost) when these authorities regulate and it reduces to 0 when they don't regulate.

The expected returns of food enterprises is E_f .

$$E_f = x\cdot(R-C-C_1(x)) + (1-x)\cdot(-C-G)$$
$$= (R+G)\cdot x - C_1(x)\cdot x - (C+G) \quad (1)$$

The participation constraint of the food enterprises is

$$R-C-C_1(x) > -C-G$$

i.e. $$C_1(x) < (R+G)\ ,\quad x < \sqrt{(R+G)/a} \quad (2)$$

Single-period incentive compatibility constraint (to maximize their own income) of food enterprises is:

$$\max_x E_f = \max_x\{(R+G)\cdot x - x\cdot C_1(x) - (C+G)\} \quad (3)$$

i.e. $$\frac{\partial E_f}{\partial x} = \frac{\partial}{\partial x}\{(R+C)\cdot x - x\cdot C_1(x) - (C+G)\} = 0 \quad (4)$$

Substitute $C_1(x) = ax^2$ into formula (3), we get

$$x = \sqrt{(R+G)/3a} \quad (5)$$

Therefore, food enterprises can achieve maximal expected returns when product pass rate satisfies formula (5).

3.2 Analysis of repeated game model

It is a long process for government to regulate food enterprises. It can be said that as long as people need food, regulation behavior will always have to continue. Because both sides of the game know the game will be ongoing for a long time, their judge for returns must be different from that in a single short game, which therefore affects their behaviors at different stages in repeated game process. Different behaviors decide that the final returns of both sides are not a simple superposition of the single shot game returns.

3.2.1 Design of optimal food pass rate

When pass rate x satisfies formula (2), i.e. $x < \sqrt{(R+G)/a}$, it is easy to prove that: when food enterprises choose to produce qualified food and government regulators choose to regulate, both sides has higher efficiency, which is the potential foundation for bilateral cooperation.

Taking into account the time value of money, set the discount rate as δ , $\delta = 1/(1+\gamma)$, in which γ is the market interest rates at some stage.

If food enterprises choose to produce unqualified food at a stage without being discovered, they will achieve $R - C$. At next stage government regulators enhance regulation, which leads to forever returns $-C - G$. Total returns can be expressed as:

$$E_f = R - C + (-C - G)\cdot\delta + (-C - G)\cdot\delta^2 + \cdots(-C - G)\cdot\delta^n$$

$$= R - C - \sum_{n=1}^{\infty}(C+G)\cdot\delta \qquad \text{(obviously } \because 0<\gamma<1 \therefore 0<\delta=\frac{1}{1-\gamma}<1\text{)}$$

$$= R - C - (C+G)\cdot\frac{\delta}{1+\delta} \tag{6}$$

If food enterprises always choose to produce qualified food, we will set E_F as the present value of total returns when food enterprises adopt optimal choice at every stage in repeated game and their returns at next stage will be converted into present value:

$$E_F = R - C - C_1(x) + \delta\cdot E_F$$

$$E_F = \frac{R - C - C_1(x)}{1-\delta} \tag{7}$$

Thus, when $R - C - (C+G)\cdot\dfrac{\delta}{1-\delta} < \dfrac{R - C - C_1(x)}{1-\delta}$, i.e. $\delta > \dfrac{a}{R+G}\cdot x^2$ (8)

food enterprises will adopt the strategy of producing qualified products.

1) When food pass rate satisfies $x < \sqrt{(R+G)/a}$ and the discount rate $\delta > \dfrac{a}{R+G}\cdot x^2$, food enterprises obtain the maximal returns $\dfrac{2\delta}{3(1-\delta)}(R-C)$.

I will prove it following. Suppose that E_G^* stand for total returns of food enterprises.

$$E_G^* = (R - C - C_1(x))\cdot\sum_{n=1}^{\infty}\delta^{n-1}\cdot E_f = \frac{\delta}{1-\delta}\cdot E_f\cdot(R - C - C_1(x)) \tag{9}$$

Put formula (1) and formula (5) into formula (9), we get $E_G^* = \dfrac{2\delta}{3(1-\delta)}(R-C)$.

2) When $x < \sqrt{(R+G)/a}$ and $\delta \le \dfrac{a}{R+G}\cdot x^2$, because of the low discount rate, the future returns have little importance to food enterprises. They are more likely to choose the behavior for quick success and instant benefit. They will at any time do shoddy work and use inferior materials and even fail to produce in accordance with the technical requirements, which will reduce variable cost in order to obtain maximal returns.

3) When $x < \sqrt{(R+G)/a}$, the returns of producing qualified food are less than that of producing unqualified food, and food enterprises will not choose to improve product pass rate unlimitedly, which is obviously in line with production rules.

3.2.2 Impact of government regulators behavior on food enterprises

1) Punishment *G* of government regulators determines the production mode of food enterprises directly

It is known from Table1 that when $R - C - C_1(x) < -C - G$, i.e. $R + G < C_1(x)$, punishment *G* of food enterprises is not enough, and producing unqualified food earns better than producing qualified food. It will lead to regulate failure. At this point, to increase punishment *G* is the most simple and effective way.

From formula (8), the greater the punishment *G*, the smaller the value range of γ, which causes food enterprises to decrease future expectation and thereby bring about negative reality. It can be seen from another perspective that increasing food pass rate *x* can also increase value range of γ and offset the impact of *G*. It is proved that to increase punishment *G* has a direct impact on urging food enterprises to increase food pass rate.

2) Punishment *G* of government regulators influences expected returns of food enterprises

We get from formula (1) that: $\frac{\partial E_f}{\partial G} = x - 1$, ∵definition of x, therefore $0 \le x \le 1$, ∴ $\frac{\partial E_f}{\partial G} \le 0$. It can be proved that with the increase of punishment *G*, expected returns of food enterprises will decrease. Thus, how to maintain an appropriate punishment *G* is an issue worthy of study.

4 Conclusion

This paper aims at the China's prominent food safety problem in recent years in the process of enhancing regulation by relevant government departments. It takes government regulators and food enterprises as a research focus, quantifies the relationship and returns of the two parties concerned and uses repeated game and discount rate to analyze the interactive process between food enterprises and government regulators. Based on model analysis it also discusses the optimum of food enterprises product pass rate under the existing relationship and research the impact of government regulators punishment on food enterprises. The result shows that a key factor to influence food enterprises product pass rate is the punishment of government regulators, the increase of which will greatly increases product pass rate. Meanwhile, food enterprises' current policies adopted are decided by the future expectation of them. In short the only and feasible solution is to increase product pass rate of food enterprises under the long-term and strict regulation from government regulators.

The significance of this work is that although there are rapid changes in modern society, ongoing game relationship still benefits the common interests. As long as we give a system to ensure the appropriate constraints, we can build a harmonious, honest society.

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