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A Effective Way to Improve the Performance of Food Safety Governance Based on Cooperative Game

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Abstract

This paper applies cooperative game theory to develop a model for food safety governance and analyzes the process of which the government, the market and the third sector take party in food safety governance and achieve game balance. The research result is that the performance improvement of food safety governance should be based on the cooperative mechanism of which government, market, and the third sector. Therefore, it is essential for us to take some measures to establish a coordinate mechanism of which the government, the market, and the third sector participate in the food safety governance.

Keywords: Cooperative Game; Effective Way ; Food Safety; Governance; Performance

1. INTRODUCTION

Since the 1990s, China's food industry growing rapidly. The total output of meat, aquatic products, and sugar increased by 205.19 per cent, 320.36 per cent, 69.92 per cent in 2009 respectively more than that of the 1990[1]. The food industry has become an important pillar industry in China. However, the serious incidents of food safety have occurred frequently. 95.8 per cent of urban consumers and 94.5 per cent of rural consumers concerned about food safety issues in 2008[2]. This background leads to an urgent study on food safety issues. Many scholars have put forth different points of view on the relationship between the protagonist's behavior and food safety. The majority of food in market are not only experience goods but also credence goods (Caswell and Padberg, 1992) [3], food suppliers will take adverse selection as the optimal strategy in the absence of third-party monitoring mechanism. Obviously, government is important manager(Zhou De-yi, Yang Hai-juan，2002；Wang Xiu-qing，2002) [4-5].

But the government mechanism always focuses on the construction of laws and standards of food safety, while neglects the implementation cost of specific regulations or standards and the benefit game between different protagonists in the market; and it leads to government failure（Henson and Caswell, 1999）[6]. Many overseas researchers believed that market mechanism and government mechanism have their faulty, and thought that food

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safety governance should concern inter action of the different protagonists: government's regulatory, consumer's participation, producer's obedience, and so on (Henson, et a1, 2001) [7].

The above researches are theoretical basis of this paper. But in china, the study on food safety began in the late 1990s. The majority of domestic literatures analyzed the food safety issues from the point of view on the relationship between the government and the market, and emphasized the impacts of the government and the market on food safety, but ignored the role of social forces, and "the majority of researches are qualitative" [8]. Our view is that food suppliers, government, and food industry association in modern market economy are the three protagonists affecting food safety, and their cooperative behavior in production, circulation, and consumption impact directly on the level of food safety. So, food safety should be understood on the base of the cooperative relationship of among the government, the food suppliers, and the social intermediary organizations. Based on the previous studies, this paper established a model for multipartite participation in food safety governance, and tries to reveal the effective way to enhance the performer of food safety governance.

2. MODEL

2.1 Benefits distribution model

In the real market environment, the protagonists are limited rationality. "Their behavioural change are slow evolution rather than rapid learning or adjustment, therefore, we can simulation the process by the copy dynamic mechanism of biology evolution, that is the evolutionary stable strategy (ESS)" [9].When food safety problem appearances, government, food suppliers and food industry association play games with each other continuously for their rights and interests in the market. So, we can construct a dynamic game model for the cooperate behavior of protagonist's food safety governance based on evolutionary game theory. We suppose that player's game sets is $H = (1, 2, 3, \cdots, n)$ .T_i refers to the strategy decisions of each player, i=1，2，…，n; and its pure strategies sets is

$$T(i) \equiv \{t^{(i)}{}_1, t^{(i)}{}_2, \cdots, t^{(i)}{}_{ji}\} \tag{1}$$

Each player i's mixed strategic sets is

$$c^{(i)} \equiv \{C^{(i)}{}_1, C^{(i)}{}_2, \cdots, C^{(i)}{}_{ji}\} \tag{2}$$

Where, $C^{(i)}{}_{\delta i} \geq 0, \sum_{\delta i=1}^{ji} C^{(i)}{}_{\delta i} = 1$. F_i refers to each player's payoffs function, where, i=1，2，…，n.

When $\delta \equiv \{t_{\delta 1}{}^{(1)}, t_{\delta 1}{}^{(2)}, \cdots, t_{\delta 1}{}^{(n)}\}$，$F^{(i)}{}_{\delta}$ refers to random player i's income, where, the number of income are $j_1 \times j_2 \times \cdots \times j_i \times \cdots \times j_n$.

Where, δ_1=1，2，…，j_1 ,δ_2=1，2，…，j_2, δ_i=1，2，…，j_i, δ_n=1，2，…，j_n ,δ=1，2，…，$j_1 \times j_2 \times \cdots \times j_i \times \cdots \times j_n$ .Based on evolutionary game theory, we construct a general model of each player's strategy, that is

$$P \equiv (\Gamma, \{T_i\}_{i \in n}, \{F_i\}_{i \in n}) \tag{3}$$

We assumed that $C^{(i)}{}_{\delta i}$ is random player i's evolutionary stable strategy, and his expected payoff of ESS more than that of other strategies. Even if other player not choose ESS, player i's expected income of ESS more than that of other strategies. That is

$\forall C^{(i)}{}_{\delta i} \neq C^{(i)}{}_{\delta i'}$ Where, $C^{(i)}{}_{\delta i'} \in C^{(i)}{}_{\delta i}$, and then,

$$E^{(i)}{}_{\delta i1}(C^{(i)}{}_{\delta i}, (C^{(1)}{}_{\delta i}, \cdots, C^{(i-1)}{}_{\delta i-1}, C^{(i+1)}{}_{\delta i+1}, \cdots, C^{(n)}{}_{\delta n})) \geq$$

$$E^{(i)}{}_{\delta i1}(C^{(i)}{}_{\delta i}, (C^{(1)}{}_{\delta i}, \cdots, C^{(i-1)}{}_{\delta i-1}, C^{(i+1)}{}_{\delta i+1}, \cdots, C^{(n)}{}_{\delta n})) = E^{(i)}{}_{\delta i1'}(C^{(i)}{}_{\delta i'}, (C^{(1)}{}_{\delta i}, \cdots, C^{(i-1)}{}_{\delta i-1}, C^{(i+1)}{}_{\delta i+1}, \cdots, C^{(n)}{}_{\delta n}))$$

Implies

$$E^{(i)}{}_{\delta i2}(C^{(i)}{}_{\delta i}, (C^{(1)}{}_{\delta i}, \cdots, C^{(i-1)}{}_{\delta i-1}, C^{(i+1)}{}_{\delta i+1}, \cdots, C^{(n)}{}_{\delta n})) > E^{(i)}{}_{\delta i2'}(C^{(i)}{}_{\delta i'}, (C^{(1)}{}_{\delta i}, \cdots, C^{(i-1)}{}_{\delta i-1}, C^{(i+1)}{}_{\delta i+1}, \cdots, C^{(n)}{}_{\delta n}))$$

Copy dynamic equation is the key of game analysis. When player i choose $C^{(i)}{}_{\delta i}$, his copy dynamic equation is

$$\frac{\partial C^{(i)}{}_{\delta i}}{\partial k} = C^{(i)}{}_{\delta i}(E^{(i)}{}_{\delta i} - E^{(i)}) \tag{4}$$

Where, $E^{(i)}{}_{\delta i}$ refers to player i's expected income. $E^{(i)}$ refers to player i's total expected income in the entire game, and $C^{(i*)}{}_{\delta i}$ the equilibrium point of evolutionary stable strategy.

When $\frac{\partial C^{(i)}{}_{\delta i}}{\partial k} = 0$, copy dynamic equation can be zero. The value of ESS must be equilibrium value, and it can correct strategic decisions deviation from equilibrium value. If some disturbance cause $C^{(i)}{}_{\delta i} > C^{(i*)}{}_{\delta i}$, and then, $\frac{\partial C^{(i)}{}_{\delta i}}{\partial k}$ must be less than zero. When $C^{(i)}{}_{\delta i} < C^{(i*)}{}_{\delta i}$, $\frac{\partial C^{(i)}{}_{\delta i}}{\partial k}$ must be more than zero, that is, $\frac{\partial^2 C^{(i)}{}_{\delta i}}{\partial k^2} < 0$, the slope is negative. The communication between game players will be stopped when they achieve the point of evolutionary stable strategy. Game players, who are limited rationality man, can achieve Nash equilibrium eventually through communication.

2.2The evolutionary game model of tripartite benefits distribution: government, industry associations, and food supplies

For the convenience of analysis, we propose following assumptions:

(1) There are three protagonists in food market: *G* refers to government whose goal is the pursuit of public interest; *Y* refers to food industry association whose goal is the pursuit of some public benefits; *R* refers to food suppliers whose goal is the pursuit of private interests. They are all limited rationality economical men. (2) Each player has two strategies. Food suppliers supply safety food or unsafe food. The government chooses active supervision or passive supervision. Food industry association actively protect industry reputation or passively.

According to the assumption (2), we can deduce player's randomly strategy choices, and can be shown as Tab.1. Game players are limited rationality economical men. So, they do not choose the optimal strategy based on completely rational assumption at beginning of the game. We assume that the probability of player *G* choosing option 1 is p_1, and then, his probability of choosing option 2 is 1-p_1.The same as player *G*, the probability of player *Y* choosing option 1 is p_2, and then, his probability of choosing option 2 is 1- p_2; the probability of player *R* choosing option 1 is p_3, and then, his probability of choosing option 2 is 1-p_3.When the game beginning, one player may meet the other two players who choose the same strategies or the different strategies. One player's payoff depends on not only his own strategy decision, but also the other two player's strategy decision. Each player's payoff matrix as shown Tab.2.

(1, 1, 2) refers to the low payoff, that is, the worst outcome of the game between government, industry associations, and food suppliers. It occurs if government makes the conflict laws or regulations based on its own interests, the interests of industry associations are inconsistent with the public interest, and food enterprises affected by multiple regulations. Now, China's food safety facing two major obstacles: one is legal barriers, another is institutional barriers. The two obstacles are the low payoffs. Legal barriers including the lag in the construction of food safety laws, the lack of harmony in food safety standards, and inadequate supervision, and so on. Institutional barriers including too much government oriented, food safety regulated by multi sectors, the neglect of the function of industry associations in food safety management.

(1, 2, 4) refers to the high payoff, that is, the best outcome of the game between government, industry associations, and food suppliers. It means that government provides the better institutional environment for producing safety food; industry associations help food suppliers improve their management level, the operation of food suppliers running under a perfect legal system. On the other word, each of them obtains the maximizing interesting from the stability and coordination environment. But, each of players does not know the optimal strategies because he is limited rationality economical man. So, system should be perfected based on the common effort of government, industry associations, and food suppliers.

Tab.1 The payoff matrix of three-player

		Y	
		option 1	option 2
G	option 1	(a^1, a^2, a^3)	(b^1, b^2, b^3)
	option 1	(c^1, c^2, c^3)	(d^1, d^2, d^3)

When *R* chooses the option 2：

		Y option 1	Y option 2
G	option 1	(s^1, s^2, s^3)	(z^1, z^2, z^3)
	option 1	(y^1, y^2, y^3)	(m^1, m^2, m^3)

Tab.2 The payoff matrix in the case

When *R* chooses option 1, matrix 1 is

		Y option 1	Y option 2
G	option 1	(1, 1, 2)	(1, 3, 2)
	option 1	(1, 1, 2)	(2, 3, 2)

When *R* chooses option 2, matrix 2 is

		Y option 1	Y option 2
G	option 1	(1, 1, 4)	(1, 3, 3)
	option 1	(2, 1, 4)	(2, 3, 4)

When the player *G* choose option 1, then

$$F^{(G)}{}_{\delta} = (a^1, b^1, s^1, z^1) = (1,1,1,1) \quad (5)$$

Expected payoff is

$$E^{(G)}{}_1 = \sum_{\partial_Y=1}^{2} \sum_{\delta_R=1}^{2} F^{(G)}{}_{\delta} \times C^{(Y)}{}_{\delta_Y} C^{(R)}{}_{\delta_R}$$
$$= F^{(G)}{}_1 \times C^{(Y)}{}_1 \times C^{(R)}{}_1 + F^{(G)}{}_2 \times C^{(Y)}{}_2 \times C^{(R)}{}_1 + F^{(G)}{}_3 \times C^{(Y)}{}_2 \times C^{(R)}{}_2$$
$$+ F^{(G)}{}_4 \times C^{(Y)}{}_1 \times C^{(R)}{}_1$$
$$= a^1 p_2 p_3 + b^1(1-p_2)p_3 + b^1(1-p_2)p_3$$
$$+ s^1(1-p_2)(1-p_3) + z^1 p_2(1-p_3) = 1 \quad (6)$$

When the player *G* choose option 2, then

$F^{(G)}{}_{\delta} = (c^1, y^1, d^1, m^1) = (2,2,2,2)$, Expected payoff is

$$E^{(G)}{}_2 = \sum_{\delta_Y=1}^{2} \sum_{\delta_R=1}^{2} F^{(G)}{}_{\delta} \times C^{(Y)}{}_{\delta_Y} \times C^{(R)}{}_{\delta_R}$$
$$= c^1 p_2 p_3 + d^1(1-p_2)p_3 + y^1(1-p_1)(1-p_2) + m^1 p_2(1-p_3) = 2 \quad (7)$$

The player *G*'s average expected payoff is

$$E^{(G)} = C \times E^{(G)}{}_1 + (1-C) \times E^{(G)}{}_2 = 2 - C \quad (8)$$

The player *G*'s copy dynamic equation is

$$\frac{\partial C}{\partial K} = C(E^{G}{}_1 - E^{(G)}) = C^2 - C \quad (9)$$

Let $\frac{\partial C}{\partial k} = 0$, and $\frac{\partial C}{\partial k} < 0$. We can obtain the point (c*), that is, the player *G*'s evolutionary sable strategy. Based on the above analysis, player *Y*'s copy dynamic equation is:

$$E^{(Y)}{}_1 = 1, E^{(Y)}{}_2 = 3, E^{(Y)} = 3 - 2p_2, \frac{\partial p_2}{\partial K} = 2p_2{}^2 - 2p_2 \quad (10)$$

The player *R*'s copy dynamic equation is:

$$E^{(R)}{}_1 = 1, E^{(R)}{}_2 = 4, E^{(R)} = 4 - 2p_3, \frac{\partial p_3}{\partial K} = 2p_3{}^2 - 2p_3 \qquad (11)$$

2.3 The solution of ESS equilibrium

We first analyze the copy dynamic equation of two-player game, evolutionary stable strategy and its equilibrium. Secondly, we analyze the third player's evolutionary stable strategy, and then calculate three-player's the solution of ESS. Therefore, we suppose that the player *R* chooses option 1, and then, three-player game turn into two-player game. Its payoff matrix is as shown Tab.3.

Tab.3 The payoff matrix after predigestion

		Y: option 1	Y: option 2
G	option 1	（1，1）	（1，3）
	option 1	（1，1）	（2，3）

The player *G*'s copy dynamic equations are:

$$E^{(G)}{}_1 = p_2a^1 + (1-p_2)b^1 = 1, E^{(G)}{}_2 = p_2c^1 + (1-p_2)d^1 = 2$$

$$E^{(G)} = 4 - 2p_1, \frac{\partial p_1}{\partial k} = p_1{}^2 - p_1 \qquad (12)$$

So, the player *G*'s ESS equilibrium solution is $p_1* = 0$. The player *Y*'s copy dynamic equation is:

$$E^{(Y)}{}_1 = p_1a^2 + (1-p_1)c^2 = 1, E^{(Y)}{}_2 = p_1b^2 + (1-p_1)d^2 = 3$$

$$E^{(G)} = p_2E^{(Y)}{}_1 + (1-p_2)E^{(Y)}{}_2 = 3 - 2p_2, \frac{\partial p_2}{\partial k} = 2p_2{}^2 - 2p_2 \qquad (13)$$

So, the player *Y*'s ESS equilibrium solution is $p_2* = 0$. From the above analysis , as the limited rationality economical men, although player *G* and player *Y* can not attain the optimal strategy at the beginning of the game, they can attain the game equilibrium through repeated games, mutual communication, and decision adjusting. That is, player *G* and player *Y* all choose option 2. For player *R,* obviously, if the one choose some strategy, the other two may obtain similar game equilibrium. After three-player game finished, equilibrium must be occurring, that is, *G, Y, R* all choose option 2, the solution is（2，3，4）.

3. CONCULTION

The development of modern market economy has made food supply chain become longer and longer. The number of stakeholders in the food supply chain increasing, and their behavior affects directly food safety. However, for the limited rationality, each stakeholder can not solve the problem of food safety by himself. In the process of food safety management, each stakeholder seeks the optimal strategy though trying error constantly, self-adjust and mutual learning. Based on the above model analysis, there is a solution which can make government, industry associations, and food suppliers achieve the point of game equilibrium.

It shows us that the efficiency of food safety governance depends on the cooperative behavior of government, industry associations, and food suppliers. It shows us that multipartite cooperative governance of food safety can set up learning organizations among the government, food industry associations and food suppliers, and stimulate the initiative of which the other social members participate in the food safety governance, and cause the high payoff of the game and produces a positive effect on the improvement of food safety. Therefore, it is essential for us to take some measures to establish a coordinate mechanism of which the government, the market, and the third sector participate in the food safety governance. These measures including change the model of government oriented in food safety management, and promote food supplier's self discipline, construct the institutional environment of which the food industry associations involved in food safety management.

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