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Research on The Evolutionary Game of Government Regulation for Production Safety Service Based on Adverse Selection

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Abstract: This paper analyzed the adverse selection of safety production services, and established the behavior payment matrix between safety production service agencies and government related department using evolutionary game theory. Through the analysis of the evolution model, the influence of individual behavior on group behavior is revealed and the evolution of the system is analyzed. Suggestions are put forward on how to avoid bad state and evolve to good state.

Keywords: evolutionary game; production safety service; government regulation

1 Introduction

In recent years, the government has been vigorously cultivating the production safety socialized services, stripping the security services provided by the government in the past and giving it to the service agencies, and stimulating enterprises to purchase the production safety socialized services. On December 31, 2016 the State Council issued "Guiding opinions on accelerating the construction of the production safety socialized services" (Safety Commission 2016 No.11). It proposed to "accelerate the establishment of a new the production safety social services, with multi subjects, comprehensive coverage, comprehensive support, flexible mechanism, flexible and efficient operation". So far, the production safety socialized service market has been developing rapidly. Before enterprises purchase the production safety socialized services, they cannot judge the quality of the services caused by asymmetric information. Enterprises usually make purchase decisions according to price. Some service agencies provide lower level services with higher price. It will lead to bad money drives out good. Then enterprises will have the services by themselves instead of buying from service agencies, which will prevent the formation and development of the production safety socialized services. Therefore, it is essential to research on how to improve the supply level of the production safety socialized services.

Some scholars have studied the necessity of the formation of the production safety socialized services market. Hasle et al. [1] found that service organizations played a key role in guiding enterprises to carry out safety in production through the pilot projects in Denmark. Yin Jiankang [2] proposed it was important to establish an organization that performs specific social functions to satisfy the needs of safety work. Dong Lijuan [3] compared and analyzed the market model of production safety service domestic and overseas, then provided some suggestions for the marketization of safety production services in China.. Huang Yuecheng [4] studied the related subjects of safety production services and established the safety production mechanism model of five main bodies. Some scholars have studied effective operation of the socialized production service market. Zhong Jingjing [5] found that the internal cost and transaction efficiency of production safety service play a decisive role in the socialized supply of safety production services. Liu Suxia [6] drew a conclusion that enterprises and service behaviors are affected by such factors as government safety regulation, service cost and service ability. Nunez [7] found that enterprise was affected by service cost, the limitation of enterprise's own resources and the mechanism of enterprise decision-making when the enterprise purchased the socialized service of production safety. According to the research and analysis presented abovethere is seldom research on the interaction process and behavior choice between subjects.

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This paper analyzes the behaviors and interactions between administration and service agency which affect the supply level of the production safety socialized services. The game model is established explore the path to improve the service quality level of production safety, and to promote the development of socialized service market.

2 Model Assumption

At present, the government encourages enterprises to purchase safe production services, and accelerates the building of the production safety socialized service system. To protect the quality of service, the service agencies should be regulated by the related government departments. This process involves the related government departments and service agencies. Whether the service agencies provide high-quality service is the result of the game between the two sides. Given the limited rationality of both parties, the government departments and service agencies will have difficulty in deciding whether to maximize the benefits when they make their own decisions because of the information asymmetry. For the convenience of research, this paper makes the following assumptions:

Hypothesis 1: the relevant government departments can choose if to regulate the service providers to provide truthful and reliable information. Strategic set of the relevant government departments: $A = \{\text{regulate, not regulate}\}$. Once the relevant government departments choose regulation, the deception behavior of services will be discovered;

Hypothesis 2: Service agencies deceive or not deceive their truthful information. Service strategy set $B = \{$deception, not deception$\}$

Hypothesis 3: The aim of service agencies is to maximize the profit. So, in the absence of regulation, service agencies will provide a low-quality service and take the strategy of deception.

Hypothesis 4: Given constraints, service agencies and the relevant government departments always maximize their own interests. They are constantly trying and progressing a dynamic game process in terms of information asymmetry and bounded rationality.

The cost of the relevant government departments is C, when they choose to regulate, including the cost of manpower, material resources, financial resources, and information costs.

When the service agencies choose to deceive, they will provide lower-quality service with higher price. They get profit from price differences. This profit is B. While the government departments choose to regulate and punish, the punishment given to agencies is F. Service agencies should undertake rectifying and reform. Then the accident rate decrease from f_1 to f_2 $(f_1 > f_2)$. If the government departments don't choose to regulate, the accident rate is f_1, and the loss of government is S_2, and the loss of agencies is S_1.

When the service agencies truthfully report the level of service quality, they will improve the reputation. So the profit they get is R_1. At the same time, the profit that government get is R_3 $(R_3 > R_2)$. The reward that agencies get from government is E.

The probability that the government will regulate is p, The probability that the agencies will deceive is q.

Thus, the pay-off matrix as follows:

Table 1: The Game Pay-off Matrix Between the Relevant Government Departments and the Service Agencies

		The relevant government departments	
	Strategy	regulation (p)	No regulation $(1-p)$
The service agencies	Deception (q)	$B-F, R_2-C-f_2S_2$	$B-f_1S_1, -f_1S_2$
	Not deception$(1-q)$	$R_1+E, R_3-C-f_2S_2$	$R_1, R_3-f_2S_2$

3 Model Evolution

According to the hypothesis, we can establish the dynamic rules of the game between the relevant government departments and service agencies. Modified complex dynamic equation [8] as follows.

The expected of benefit for regulation is v_1, and the expected of benefit for no regulation is v_2. The average benefit is

$\bar{v}$,

$$v_1 = q(R_2 - C - S_2 f_2) + (1-q)(R_3 - C - S_2 f_2), \tag{1}$$

$$v_2 = q(-f_1 S_2) + (1-q)(R_3 - S_2 f_2). \tag{2}$$

The expected of benefits for deception is u_1, and the expected of benefits for no deception is u_2. The average benefit is $\bar{u}$,

$$u_1 = p(B - F) + (1-p)(R_1 + E), \tag{3}$$

$$u_2 = p(B - f_1 S_1) + (1-p)R_1. \tag{4}$$

According to the Malthusian dynamic equation, because the growth rate of the strategy is equal to the relative fitness, if a strategy is adopted, the individual meet degree is higher than the average in the population, then the strategy will increase.

Replicated dynamic equation of government is as follow:

$$F_1(p,q) = p(1-p)(qR_2 - C + qS_2(f_1 - f_2)). \tag{5}$$

And replicated dynamic equation of service agencies is as follow:

$$F_2(p,q) = q(1-q)(E + p(f_1 S_1 - E - F)). \tag{6}$$

Then we get dynamic equations of games as follows:

$$\begin{cases} \frac{dp}{dt} = F_1(p,q), \\ \frac{dq}{dt} = F_2(p,q). \end{cases} \tag{7}$$

This system is studied by means of dynamic system analysis. According to (7), direct computation, we have following local equilibrium points: $(0,0)$, $(0,1)$, $(1,1)$, $(1,0)$ and (p_*, q_*), where $p_* = \frac{E}{E+F-f_1S_1}$ and $q_* = \frac{C}{S_2(f_1-f_2)+R_2}$.

4 Model Analysis

The stability of the five local equilibrium points is studied by the linearization method. The Jacobi matrix is as follows:

$$J = \frac{\partial(F_1,F_2)}{\partial(p,q)} = \begin{bmatrix} (1-2p)(q(R_2+S_2(f_1-f_2))-C) & p(1-p)(R_2+f_1-f_2) \\ q(1-q)(f_1S_1-E-F) & (1-2q)(E+p(f_1S_1-E-F)) \end{bmatrix}.$$

There are four ordinary equilibrium points: $(0,0)$, $(0,1)$, $(1,1)$, $(1,0)$. The results of the stability analysis are shown in table 2.

Table 2: The conclusion of the stability of four trivial equilibrium points.

	Eigenvalues	Type
(0,0)	$\lambda_1 = -C < 0, \lambda_2 = E > 0$	Saddle point
(0,1)	$\lambda_1 = R_2 + S_2(f_1 - f_2) - C > 0, \lambda_2 = -E < 0$	Saddle point
(1,1)	$\lambda_1 = -(R_2 + S_2(f_1 - f_2) - C) < 0, \lambda_2 = F - f_1S_1 > 0$ for large punishment F	Saddle point
	$\lambda_1 = -(R_2 + S_2(f_1 - f_2) - C) < 0, \lambda_2 = F - f_1S_1 < 0$ for small punishment F	stable fixed point
(1,0)	$\lambda_1 = C > 0, \lambda_2 = f_1S_1 - F < 0$ for large punishment F	stable fixed point
	$\lambda_1 = C > 0, \lambda_2 = f_1S_1 - F > 0$ for small punishment F	unstable fixed point

In fact, the results are consistent with our understanding of the issues. Let's take the point $(1,1)$ for example. The strategy of this point is regulation and deception. If punishment F is suitably large, then we have the eigenvalue $\lambda_1 < 0$ and $\lambda_2 > 0$, that means this point is a saddle point, that is to say, the evolution of activity will attract to $p = 1$, but repel to

$q = 1$, thus the evolution can't reach the point $(1, 1)$. But if the punishment F is suitably small, then both eigenvalues are negative, thus $(1, 1)$ is a stable fixed point. Then all evolution of activity, wherever it started from any state, will approach to the $(1, 1)$, that means the service agencies always choose to deceive, and the government chooses regulation.

When punishment F is suitably large, the points (1,1) and (1,0) are saddle points. While punishment F is suitably small, the point (1,1) is stable fixed point, which means that service agencies want to deceive, and the relative government departments want to regulate; the point (1,0) is unstable fixed point, which means the service agencies and the relative government departments are changing all the time.

For the whole society, it is the best situation that the service agencies choose to no deception, and the relative government departments should not regulate, which is $p = 0$ and $q = 0$. Thus we need both eigenvalues are negative at point (0,0). It means the government should give more prize to the service agencies, if the agencies don't have any deception without government's regulation. For example, the government can rank the level of service quality, and show the ranks to all, the service agencies with no deception can get additional benefits.

Next, we will discuss the equilibrium point (p_*, q_*). When punishment F is suitably small, $p_* = \dfrac{E}{E+F-f_1S_1}$ which is beyond the range of p, so the fixed point is not considered. When punishment F is suitably large, then we have $p_* = \dfrac{E}{E+F-f_1S_1} \in (0, 1)$, $q_* = \dfrac{C}{S_2(f_1-f_2)+R_2} \in (0, 1)$. And the corresponding Jacobi matrix J_* is as follows:

$$\begin{bmatrix} 0 & p_*(1-p_*)(R_2+f_1-f_2) \\ q_*(1-q_*)(f_1S_1-E-F) & 0 \end{bmatrix},$$

and corresponding characteristic equation

$$\lambda^2 + p_*q_*(1-p_*)(1-q_*)(R_2+f_1-f_2)(E+F-f_1S_1) = 0.$$

Therefore, the characteristic root is a pair of conjugate imaginary Numbers. This is a critical situation, and cannot be dealt with by linearization. The method of the Lyapunov function should be considered. But in general, there is no general method for constructing Lyapunov function and it is very difficult, and the same is true here. But we observe equation (7), if we introduce variables $\tilde{p} = \ln\frac{p}{1-p}$ and $\tilde{q} = \ln\frac{q}{1-q}$, where $\tilde{p}$ is the monotone function of p, and $\tilde{q}$ is the monotone function of q,the equation (7) can be transformed as follows:

$$\begin{cases} \dfrac{d\tilde{p}}{dt} = q(\tilde{q})(R_2+S_2f_1-S_2f_2)-C, \\ \dfrac{d\tilde{q}}{dt} = p(\tilde{p})(f_1S_1-E-F)+E. \end{cases} \tag{8}$$

We notice that the right at this point is a linear function of p and q, and p and q are monotone functions about $\tilde{p}$, $\tilde{q}$. Therefore, the stability of the point (p_*, q_*) in the equation is consistent with the stability of the point (p_*, q_*) in the following equation

$$\begin{cases} \dfrac{dp}{dt} = q(R_2+S_2f_1-S_2f_2)-C, \\ \dfrac{dq}{dt} = p(f_1S_1-E-F)+E. \end{cases} \tag{9}$$

Then we can calculate directly by standard ODE theory [9] that the equation (9) is unstable at the point (p_*, q_*).

5 Conclusion

The game studied in this paper is the behavior choice of the relevant government department and service agencies after considering the factors such as punishment, reward and regulatory costs. In this process, there is a bad state that the service agencies willing to deceive, and government departments should supervise. To get out of the bad state, government should encourage the agencies which do not deceive. Therefore, the agencies should be classified into distinct levels and the results should be shown to all. Therefore, integrity and orderly agencies will gain additional benefits which can speed up the healthy development of the market.

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