ICIC Express Letters
Volume **15**, Number **8**, August **2021**

 ISSN 1881-803X
pp. 845–851

GAME RESEARCH ON FOOD SAFETY SUPERVISION ON ONLINE CATERING PLATFORM

Yang Liu[1,*], Yuxin Han[1] and Huipo Wang[2]

[1]School of Economics and Management
Dalian University
No. 10, Xuefu Street, Jinzhou New District, Dalian 116622, P. R. China
[*]Corresponding author: liuyang3@dlu.edu.cn

[2]School of Management Engineering and Business
Hebei University of Engineering
No. 19, Taiji Rd., Handan Economic & Technological Development Zone, Handan 056038, P. R. China
wanghuipo@aliyun.com

Received December 2020; accepted February 2021

Abstract. *Food safety incidents on online catering platforms have attracted more and more attention. The fundamental reason is that the supervision of the sellers on the platform lacks interest-driven. At this time, it is necessary for the government to encourage and guide online catering platforms, formulate effective legal provisions and provide incentives and punishment measures to regulate the supervision behaviors of online catering platforms' external sellers, so as to reduce the occurrence of food safety accidents on online catering platforms. In this paper, an evolutionary game model is used to analyze the evolution and stability strategy of online food safety between the government and online catering platform, and the factors affecting the participation of the government and online catering platform in supervision are solved. Among them, the severity of punishment is an important factor affecting the selection and supervision of online catering platforms.*
Keywords: Online catering platform, Supervision, Evolutionary game, Food safety

1. **Introduction.** With the development of e-commerce, the food delivery industry is developing rapidly. The scale of takeaway users has expanded rapidly. As of February 2019, the number of users has reached about 360 million. Among them, consumers who value safe food production account for 54.1%, and consumers who purchase takeaway food through online ordering platforms account for 82.6%. 44.5% of consumers have become accustomed to online food delivery services [1]. While food delivery is becoming increasingly popular among office workers and students, it has also attracted the attention of the whole society to food safety in online catering. On March 15, 2016, it was exposed that the food production environment of merchants on the "Ele.me" platform was dirty and poor, and there were a series of problems such as false propaganda on the platform, which made the platform lack of credibility. Therefore, it is necessary to strengthen food safety supervision and solve the safety problems of takeaway food.

The current research on food safety supervision is mainly carried out from the three aspects of government, media and supply chain [2]. This article focuses on the government-led online catering platform. Most of the researchers' research is limited to some problems in government supervision, so as to put forward specific solutions. For example, Liu and Li studied the shortcomings of the traditional supervision model from four aspects of supervision concept, supervision subject, supervision means, and supervision effect, so as

DOI: 10.24507/icicel.15.08.845

to innovatively propose a smart supervision model [3]. Wu found that government supervision has the dual restrictions of numerous law enforcement tasks and lack of public law enforcement resources, and thus proposed a reputation mechanism based on food safety credit files [4]. Xie et al. aimed at the problem that the government found that the probability of illegal behaviors in the food market was difficult to increase, and proposed to establish a regulatory mechanism that complements consumer deterrence signals and social consensus [5]. There are also researchers who combined government and online catering platforms into consideration. Du et al. established an evolutionary game model between government and online catering, which solved the real problems of insufficient government supervision funds and inadequate supervision [6,7]. Jian et al. studied the relationship between the government and online catering trading platforms, and how the government promotes the supervision and management of online catering online trading platforms to monitor and manage transactions, and improve the efficiency of online transaction supervision [8].

Previous studies have mostly focused on how the government and online catering platforms can cooperate and co-govern, but few scholars analyze the strategic choices and influencing factors of the government and online catering platforms from a quantitative perspective. Because the government's supervision strategy and the online catering platform supervision strategy will affect each other, this is a long-term strategy selection process and a game process under a limited rationality, so this article uses the evolutionary game model to analyze the influence of the government and the online catering platform strategy factors of choice. This paper solves the evolutionary stability strategy by constructing the evolutionary game model of the government and the online catering platform, finds the influencing factors of the government and the online catering platform, and makes targeted recommendations.

2. **Model Assumptions.** 1) Participants. There are two types of participating groups in the evolutionary game model: government and online catering platforms, both of which have bounded rationality. 2) Game strategy. The government's behavioral strategy set A = {supervised, not supervised}. The behavioral strategy set of the online catering platform B = {supervised, not supervised}. 3) Government. The cost of the government's choice of supervision is C_g, and the benefit of supervision is S_g. Due to the special nature of the government itself, its profit not only considers the material aspect, but also considers improving the happiness of the people and adding welfare to the society. In the process of government supervision, it is found that the catering business has incomplete qualifications and hidden safety hazards in the production of food. The platform will be ordered to rectify and fine the platform. The loss suffered by the online catering platform is f_t, and $f_t > C_{t1}$. If the government chooses not to regulate, the cost to the government is zero. The online catering platform that the government does not supervise and does not perform its supervisory duties has a probability of β ($0 \leq \beta \leq 1$) that the media, consumers, or higher-level departments may discover that the loss suffered by the online catering platform is still f_t. At the same time, the government will also be subject to administrative accountability from higher-level departments, and the government will be punished by f_g. 4) Online catering platform. The cost of the online catering platform to perform its supervision duties is C_{t1}, such as hiring professionals to strictly review and mark the qualifications of the restaurant (business license, sanitation permit, etc.) online, and regularly check the hygiene of the business; the cost of not performing the supervision duties is C_{t2}, if the platform is online. For qualified catering companies, obviously, $C_{t1} > C_{t2}$. The government reward for the supervision of the online catering platform is S_t, and the food safety incidents of the online catering platform are not subject to loss without supervision and by consumers or the platform merchants. If it is discovered by the government or reported by consumers that the merchant has

no production qualifications and there are hidden safety hazards in the production of food, the platform must be ordered to rectify and the platform will be punished by the government f_t. Regardless of whether the online food platform chooses to supervise or not, the service fee obtained is G_t.

3. **Construct an Evolutionary Game Model between the Government and Online Catering Platforms.** In the initial stage of the game between the government and the online catering platform, the proportion of the government choosing the "supervision" strategy is x, and the proportion of choosing the "non-supervision" strategy is $1-x$; The proportion of online catering platforms choosing the "supervised" strategy is y, and the proportion of choosing the "non-supervised" strategy is $1-y$, where $0 \leq x$ and $y \leq 1$. Then the income matrix of both parties is shown in Table 1.

Table 1. Government-online catering platform evolutionary game revenue matrix

		Government	
		supervised (x)	not supervised $(1-x)$
Online catering platform	supervised (y)	$G_t + S_t - C_{t1}$, $S_g - S_t - C_g$	$G_t - C_{t1}$, 0
	not supervised $(1-y)$	$G_t - C_{t2} - f_t$, $S_g - C_g + f_t$	$G_t - C_{t2} - \beta f_t$, $-\beta f_g$

Construct a dynamic equation for copying the behavioral strategies of the government and online catering platforms. Assuming that the government adopts the "supervision" strategy's expected return as V_{11}, the "non-regulatory" strategy's expected return is V_{12}, and the average expected return is V_1, then,

$$\begin{aligned} V_{11} &= y\left(S_g - C_g - S_t\right) + (1-y)\left(S_g - C_g + f_t\right) = S_g - C_g - yS_t + (1-y)f_t \\ V_{12} &= (1-y)\left(-\beta f_g\right) = -\beta f_g + y\beta f_g \\ V_1 &= xV_{11} + (1-x)V_{12} \end{aligned}$$

The dynamic equation of replication for constructing government behavior strategy is

$$F(x) = \frac{dx}{dt} = x(V_{11} - V_1) = x(1-x)[S_g - C_g - yS_t + (1-y)(f_t + \beta f_g)]$$

In the same way, the expected return of the online catering platform choosing the "supervised" strategy is V_{21}, the expected return of choosing the "unsupervised" strategy is V_{22}, and the average expected return of the online catering platform V_2, then,

$$\begin{aligned} V_{21} &= x\left(G_t + S_t - C_{t1}\right) + (1-x)\left(G_t - C_{t1}\right) = G_t + xS_t - C_{t1} \\ V_{22} &= x\left(G_t - C_{t2} - f_t\right) + (1-x)\left(G_t - C_{t2} - \beta f_t\right) \\ V_2 &= yV_{21} + (1-y)V_{22} \end{aligned}$$

The replication dynamic equation for constructing the behavior strategy of the online catering platform is

$$F(y) = \frac{dy}{dt} = y\left(V_{21} - V_2\right) = y\left(1-y\right)\left[xS_t + xf_t + \beta f_t - x\beta f_t - C_{t1} + C_{t2}\right]$$

Simultaneously copy the dynamic equations $F(x)$ and $F(y)$ to form the two-dimensional dynamic system of the government and the online catering platform, namely,

$$\begin{cases} \dfrac{dx}{dt} = x\left(1-x\right)\left[S_g - C_g - yS_t + (1-y)\left(f_t + \beta f_g\right)\right] \\ \dfrac{dy}{dt} = y\left(1-y\right)\left[xS_t + xf_t + \beta f_t - x\beta f_t - C_{t1} + C_{t2}\right] \end{cases}$$

4. **Seek a Stable Strategy for the Evolution of Government and Online Catering Platforms.** Participants constantly adjust their strategies according to their vested interests to pursue improvement of their own interests, and finally achieve a dynamic equilibrium strategy called evolutionary stability strategy (ESS). Before determining the evolutionary stability strategy, first find the equilibrium point of the evolutionary game. Let $F(x)$ and $F(y)$ be 0, that is, when the change rate of system strategy selection is 0, the five equilibrium points of the dynamic system can be obtained, which are $D_1(0,0)$ and $D_2(0,1)$, $D_3(1,0)$, $D_4(1,1)$, $D_5(x^*,y^*)$ $\left(x^*=\frac{C_{t1}-C_{t2}-\beta f_t}{S_t+f_t-\beta f_t},\ y^*=\frac{S_g-C_g+f_t-\beta f_g}{S_t+f_t-\beta f_g}=1+\frac{S_g-C_g-S_t}{S_t+f_t-\beta f_g}\right)$. In them, D_1, D_2, D_3, D_4 constitute the boundary of the evolutionary game domain $\{(x,y)\,|x=0,1;y=0,1\}$. The area enclosed by this is the equilibrium solution domain of the game, namely, $\{(x,y)\,|0\le x,y\le 1\}$. In this domain, there is an equilibrium point D_5 that satisfies the conditions, but D_5 is a non-progressive and stable state in a dynamic replication system composed of the government and online catering platforms, so it is necessary to discuss $D_1(0,0)$, $D_2(0,1)$, $D_3(1,0)$, $D_4(1,1)$ asymptotic stability.

According to the method proposed by Friedman, analyzing the Jacobian matrix of the system can obtain the stability of the equilibrium point of the evolutionary system. The Jacobian matrix of the above system is

$$J=\begin{bmatrix}\frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y}\\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y}\end{bmatrix}$$
$$=\begin{bmatrix}(1-2x)\left[S_g-C_g-yS_t+(1-y)\left(f_t+\beta f_g\right)\right] & -x(1-x)(S_t+f_t+\beta f_g)\\ y(1-y)(S_t+f_t-\beta f_t) & (1-2y)\left[xS_t+xf_t+\beta f_t-x\beta f_t-C_{t1}+C_{t2}\right]\end{bmatrix}$$

The evolutionary stability strategy can be obtained by copying the dynamic equation to satisfy two conditions.

1) The determinant of the Jacobian matrix detJ > 0.

2) The trace of Jacobian matrix trJ < 0.

Substitute $D_1(0,0)$, $D_2(0,1)$, $D_3(1,0)$, and $D_4(1,1)$ into the Jacobian determinant to find the detJ and trJ of each point. See Table 2.

TABLE 2. The value and trace of the determinant of the equilibrium point

The balance point	The determinant of the Jacobian, detJ	Trace trJ of the Jacobian matrix
$D_1(0,0)$	$(S_g-C_g+f_t+\beta f_g)(-C_{t1}+C_{t2}+\beta f_t)$	$(S_g-C_g+f_t+\beta f_g)+(-C_{t1}+C_{t2}+\beta f_t)$
$D_2(0,1)$	$-(S_g-C_g-S_t)(-C_{t1}+C_{t2}+\beta f_t)$	$(S_g-C_g-S_t)-(-C_{t1}+C_{t2}+\beta f_t)$
$D_3(1,0)$	$-(S_g-C_g+f_t+\beta f_t)(S_t+f_t-C_{t1}+C_{t2})$	$-(S_g-C_g+f_t+\beta f_t)+(S_t+f_t-C_{t1}+C_{t2})$
$D_4(1,1)$	$(S_g-C_g-S_t)(S_t+f_t-C_{t1}+C_{t2})$	$-(S_g-C_g-S_t)-(S_t+f_t-C_{t1}+C_{t2})$

According to the value range of x and y, the game process can be divided into six situations, see Table 3. According to the bivariate phase diagram theory [9], qualitative and quantitative analyses are combined to obtain a dynamic evolution phase diagram, as shown in Figures 1(a)-1(f).

i) Case 1, $0<x^*<1$, $y^*<0$, as can be seen from Figure 1(a), at this time, detJ > 0, trJ < 0, point $D_1(0,0)$ is the ESS point. This is because the difference between the benefits and costs when the government chooses supervision at this time is negative, that is, when the government chooses supervision, it is not profitable. Although the government itself has the public welfare nature of increasing social welfare the profit is small, it is also certain to a certain extent, the enthusiasm of government supervision is reduced. Moreover, when the government and online catering platforms choose not to supervise, the sum of the punishment received by the government and the punishment received by the platform during government supervision is less than the difference between the benefits and costs during government supervision. Obviously, the degree of punishment is an important

Table 3. The equilibrium stability of the system

Cases	x, y range	Equilibrium point	detJ	trJ	Balanced result	Dynamic evolution diagram
Case one	$0 < x^* < 1$, $y^* < 0$	$D_1(0,0)$	+	−	ESS	Figure 1(a)
		$D_2(0,1)$	−	unknown	Saddle point	
		$D_3(1,0)$	+	+	Unstable point	
		$D_4(1,1)$	−	unknown	Saddle point	
Case two	$0 < x^* < 1$, $0 < y^* < 1$	$D_1(0,0)$	−	unknown	Saddle point	Figure 1(b)
		$D_2(0,1)$	−	unknown	Saddle point	
		$D_3(1,0)$	−	unknown	Saddle point	
		$D_4(1,1)$	−	unknown	Saddle point	
Case three	$0 < x^* < 1$, $y^* > 1$	$D_1(0,0)$	−	unknown	Saddle point	Figure 1(c)
		$D_2(0,1)$	+	+	Unstable point	
		$D_3(1,0)$	−	unknown	Saddle point	
		$D_4(1,1)$	+	−	ESS	
Case four	$x^* > 1$, $y^* < 0$	$D_1(0,0)$	+	−	ESS	Figure 1(d)
		$D_2(0,1)$	−	unknown	Saddle point	
		$D_3(1,0)$	−	unknown	Saddle point	
		$D_4(1,1)$	+	+	Unstable point	
Case five	$x^* > 1$, $0 < y^* < 1$	$D_1(0,0)$	−	unknown	Saddle point	Figure 1(e)
		$D_2(0,1)$	−	−	Saddle point	
		$D_3(1,0)$	+	−	ESS	
		$D_4(1,1)$	+	+	Unstable point	
Case six	$x^* > 1$, $y^* > 1$	$D_1(0,0)$	−	unknown	Saddle point	Figure 1(f)
		$D_2(0,1)$	+	+	Unstable point	
		$D_3(1,0)$	+	−	ESS	
		$D_4(1,1)$	−	unknown	Saddle point	

factor that affects whether the two parties choose supervision or not. The penalty at the time is not large enough, making the government and online catering platforms both choose not to regulate as their evolutionary and stable strategy.

ii) Case three, $0 < x^* < 1$, $y^* > 1$, as can be seen from Figure 1(c), at this time, detJ > 0, trJ < 0, point $D_4(1,1)$ is the ESS point. This is because at this time, when the government chooses supervision, the benefits are greater than the sum of supervision costs and the rewards of the network platform for performing supervision duties ($S_g > C_g + S_t$). At this time, the government is profitable when it chooses supervision, and the government's social credibility will be improved; when the government chooses to support and the online catering platform chooses to supervise, the sum of the rewards and fines that the online catering platform obtains from the government is greater than the supervision cost of the online catering platform choosing to supervise than choosing not to supervise. That is to say, it is mutually beneficial for the government and the online catering platform to choose to supervise. At this time, both parties benefit the most. Therefore, at this time, the government and the online catering platform both choose to perform their supervisory duties. It can be seen that the size of the profit is crucial to the strategic choice of both parties.

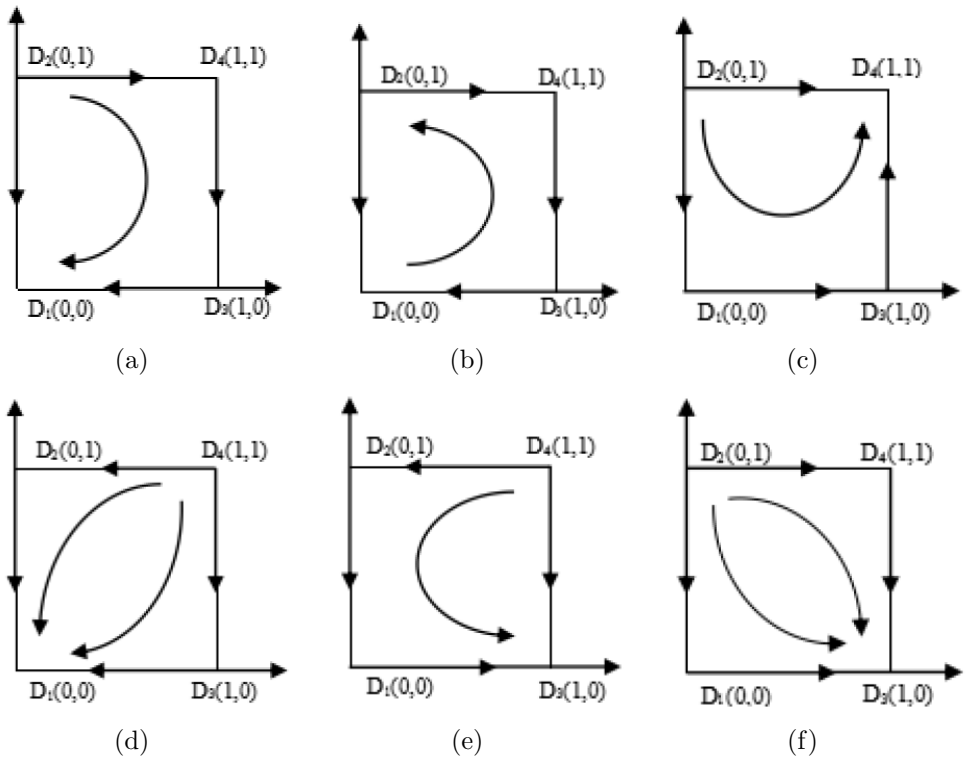

FIGURE 1. Phase diagram of dynamic evolution in six cases

5. **Conclusion.** Through the use of evolutionary game theory, it has effectively proved the important factors that affect the strategic choice between the government and the online catering platform during the game.

1) In the takeaway food industry, the development of the national economy can effectively promote the improvement of its safety. This is because with the development of the national economy, the government can effectively help and supervise online catering platforms through policies and finances. In addition, the public welfare nature of the government itself will promote the supervision of food safety with the development of the national economy.

2) The benefits of the government and online platforms affect the strategic choices of both parties. The government's revenue is lower than the supervision cost, which reduces the government's enthusiasm for supervision. It may be because the government has paid relatively large supervision costs and the benefits received are particularly small. It is not ruled out that the government receives small benefits due to factors such as incorrect supervision methods and inadequate supervision. When the government receives more benefits than the sum of the cost of supervision and the rewards to the platform, the government's supervision enthusiasm will be greatly improved, and social credibility will also increase. At this time, the government will naturally choose a supervision strategy. For online catering platforms, reducing the cost of supervision and increasing government rewards for online catering platforms will increase the probability of online catering platforms choosing a monitoring strategy.

3) Punishment is also an important factor that affects the choice of online catering platforms or not to choose supervision strategies. Drawing lessons from the suggestions made by Zheng and others in the *Investigation Report on Food Safety Supervision of the Food Delivery Industry in Zhejiang Province*, on increasing penalties, in a one-year cycle, if an online catering platform has been filed and investigated for three times in a region or a province, the communications management department will suspend the business access of the food delivery platform App in the province. Increase the penalties for illegal

activities of merchants, and strictly follow relevant laws and regulations for merchants who operate beyond the scope of business, irregular information disclosure, and abnormal business addresses [9].

In short, the development of the national economy, the cost of platform supervision, the penalties for unqualified online catering platforms, and the rewards and punishments for takeaway merchants will all directly affect the safety of takeaway food.

REFERENCES

[1] Internet Data Center, *Research Report on the Development of Online Food Delivery Service Market*, http://www.100ec.cn/detail--6498473.html, Retrieved on April 20, 2020.

[2] J. Wang, H. Wang and J. Sun, Food safety supervision strategy based on the perspective of ordering platform, *Economy and Management*, vol.34, no.3, pp.79-85, 2020.

[3] P. Liu and W. Li, Online food ordering food safety supervision: Based on the perspective of smart supervision theory, *Journal of Central China Normal University (Humanities and Social Sciences Edition)*, vol.57, no.1, pp.1-9, 2018.

[4] Y. Wu, Information foundation, reputation mechanism and law enforcement optimization – A new vision of food safety governance, *Chinese Social Sciences*, no.6, pp.115-133+207-208, 2012.

[5] K. Xie, J. Xiao, N. Yang and Y. Liu, Social deterrence signals and value reconstruction: An institutional analysis of food safety and social co-governance, *Economic Developments*, no.10, pp.4-16, 2015.

[6] J. Du, L. Zhao and L. Chen, The evolutionary game study of government and online catering pollution control, *Science and Technology Management Research*, no.14, pp.214-218, 2015.

[7] T. Yu and C. Liu, Evolutionary game analysis and simulation study of government and online catering in product quality supervision, *Chinese Management Science*, no.6, pp.90-96, 2016.

[8] J. Jian, H. Chen and B. Geng, Research on the relationship between government regulatory agencies and online catering online trading platforms based on principal-agent game, *Business Research*, no.3, pp.1-9, 2014.

[9] J. Zheng, G. Sun, Q. Ye, Y. Lu, J. Luo, B. Zhang, Y. Shen, Z. Guan, H. Shao, J. Luo and Y. Shi, Investigation report on food safety supervision of food delivery industry in Zhejiang Province, *Policy Outlook*, no.6, pp.11-15, 2020.