The Evolutionary Game Analysis and Simulation Research on E-Commerce Live Broadcast Counterfeit Sales with the Participation of a Third-Party Supervisor

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Abstract. In order to explore the impact of the participation of third-party supervision entities on the supervision of counterfeit goods in the e-commerce live broadcast market, an evolutionary game model between the live broadcast merchants and the e-commerce live broadcast platform was constructed, and the behavior of the live broadcast merchants and the e-commerce live broadcast platform was established. The conditions of strategies tending to different stable states, focusing on the analysis of the influence of the third-party supervision body's discovery of the probability of merchants selling fakes on the results of both parties' strategy selection. Using matlab to simulate the influence of different parameters such as the probability of merchants selling fake sales by third-party supervisors and the percentage of deposits deducted by non-self-disciplined merchants from the e-commerce live broadcast platform on the evolution results. The results show that as the third-party supervision entity finds that the probability of merchants selling counterfeit products decreases, merchants who live broadcast will choose a self-discipline strategy, and e-commerce live broadcast platforms will choose a non-supervision strategy to increase the corresponding probability. Merchants who live broadcast will choose a non-self-discipline strategy. The live broadcast platform will supervise the merchants who live in the live broadcast. As the third-party supervision body finds that the merchants are selling fake products, it can improve the bad situation of the e-commerce live broadcast market that is rampant. Therefore, live broadcast merchants need to be self-disciplined, e-commerce live broadcast platforms need a high degree of self-inspection, and third-party supervisors need to increase the probability of discovering merchants selling fakes in order to create a safe and civilized shopping environment for consumers.

Keywords: e-commerce live broadcast · third-party supervision body · evolutionary game · counterfeit sales

1 Introduction

Since the outbreak of the new crown pneumonia epidemic, all aspects of people's lives have been affected to varying degrees. The problem of unsalable goods have been serious,

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a large number of physical stores have closed down, and new types of e-commerce have quietly risen as a new format of the Internet economy and have become popular in China. A new type of e-commerce with "live streaming with goods" as the main form, riding on the east wind of 5G new technology, have suddenly emerged, becoming a dark horse in the field of e-commerce and forming a new "outlet" in the economic field [1]. With the rise of the "live-streaming with goods" wave, hidden consumer hazards have also emerged. Selling fakes and mixed sales of genuine and fake products have always been an urgent problem in e-commerce live broadcasts. Repeated prohibitions on the sale of fake live broadcasts by merchants stationed on the platform have severely harmed the interests of e-commerce live broadcast platforms and consumers, and restricted the healthy development of e-commerce live broadcast platforms. In October 2020, the Shanghai police cracked the first case of selling counterfeit registered trademark goods in the form of "Internet celebrity anchors with live delivery"; at the end of 2020, as Kuaishou anchor Simba was fined 2.9 million for selling fake bird's nests, unscrupulous merchants. And the inaction of the e-commerce live broadcast platform have reached the peak of public opinion. Alibaba, JD. Com and other e-commerce live broadcast platforms not only pointed out that "fake goods are the pain of China". People's Daily commented that although webcast is an emerging platform, it is not a channel to do whatever you want. Live streaming with goods cannot challenge the bottom line of the law in order to "make quick money" [2]. Therefore, this paper studies the problem of selling fake goods through live broadcast and explores effective management measures, which have certain practical significance.

Fake goods refer to products that illegal merchants use similar materials or second-hand refurbishment methods to deceive consumers by using the brand value of the goods to deceive consumers. They generally have the same price as the authentic products [3]. In the e-commerce environment, counterfeit sales are more concealed, operating costs are lower, and harm groups are wider, and the supervision of related parties is more difficult, and it have gradually attracted the attention of the academic community [4]. In existing research, e-commerce counterfeit identification systems and algorithms have been popularized earlier and are widely used. Cheung, M proposed a framework to detect counterfeit sellers by using deep learning to discover the connections between sellers from shared images [5]. Wadleigh et al. took "lemon", a typical e-commerce market, as an example, and used a quantitative method to identify and analyze the fake and inferior products on the website [6]. Experiments by Mavlanova, T, etc. show that advanced product display can reduce the sale of fakes and increase users' willingness to buy online [7]. Wu, CH, etc. used data collection to conduct empirical research on e-commerce platforms, and analyzed the dynamic performance effect mechanism of e-commerce fraud signals of counterfeit products under multi-game conditions [8]. Li Jie et al. constructed an asymmetric evolutionary game model between settled merchants and e-commerce platforms, and explored the impact of online word-of-mouth on the supervision of counterfeit goods in the e-commerce market [9]. However, current researches mostly reduce the uncertainty of product information in e-commerce from the perspective of e-commerce platforms and sellers, and there are very few third-party

supervisors involved. Therefore, with the participation of third-party supervisors, the e-commerce sales of counterfeit products are explored. The problem will be an important supplement to existing research.

Evolutionary game analysis provides a suitable analysis method for the two-way interaction between Internet celebrities and consumers. Evolutionary games can describe the learning-based strategy evolution process between groups under the condition of bounded rationality and provide a basis for macro-control group behaviors. It have become a powerful tool for analyzing the decision-making behavior of bounded rational subjects [10]. It believes that the interaction between individuals in a group is a dynamic process about the situation they face, the game environment and the state of the participants, and the game situation and the behavior of the participants are interdependent [11]. Live broadcast merchants and e-commerce live broadcast platforms, as the subject of limited rational decision-making, can introduce evolutionary games to analyze the dynamic evolution of their strategies. Therefore, this paper chooses evolutionary game as the research method, explores the results of different game strategies between live broadcast merchants and e-commerce live broadcast platforms with the participation of third-party supervision entities, characterizes the evolution process of the game behavior of both parties, and provides information for the governance of e-commerce live broadcast counterfeit sales.

2 The Evolutionary Game Model of Merchants Selling Counterfeit Products and E-Commerce Live Broadcast Platforms Under the Participation of Third-Party Supervisors

2.1 Problem Description

This article explores the dynamic evolutionary game between the supervision of e-commerce live broadcast platforms under the participation of third-party supervisors and the live-streaming merchants' sales of counterfeit products. The participants in the game are two bounded rational entities, the e-commerce live broadcast platform and the live broadcast merchants. The e-commerce live broadcast platform have two supervision strategies for its merchants, one is supervision and the other is non-supervision. The e-commerce live broadcast platform will incur a certain cost for the supervision of the merchants, and the investigation and handling of counterfeit activities will result in a certain fine; the live broadcast merchants will have There are two strategies of self-discipline and non-self-discipline. The costs of the two strategies are different. The cost of fakes is low, but fakes and genuine products have the same sales revenue. If a merchant sells fake fakes and is investigated and punished by the e-commerce live broadcast platform and third-party supervisory bodies, the corresponding percentage of deposits and fines will be deducted, which will increase the total cost of selling fakes.

Symbolize the main related terms and concepts in the problem description, as shown in Table 1.

2.2 Model Assumptions

- Hypothesis 1 The probability that the live broadcast merchant chooses the self-discipline strategy is x, $0 \leq x \leq 1$, then the probability of the non-self-discipline

Table 1. PARAMETERS AND EXPLANATION

Parameters	Explanation
W	The normal income of live broadcast merchants
C_1	Commodity costs when live-streaming merchants adopt self-discipline strategies
C_2	Commodity costs when live broadcast merchants adopt non-self-discipline strategies
C_3	The cost of active supervision of e-commerce live broadcast
C_4	The huge losses suffered by the live broadcast merchants who sell fakes when they are discovered by a third-party supervisory body
C_5	The e-commerce live broadcast platform does not supervise the huge losses suffered when discovered by a third-party supervisory entity
C_6	The cost of passive supervision of e-commerce live broadcast platforms
N_1	Platform usage fees charged by e-commerce live broadcast platforms to live broadcast merchants
N_2	The credit deposit charged by the e-commerce live broadcast platform to the merchants who live in the live broadcast
R_1	E-commerce live broadcast platforms will receive praise from the public when they are supervised
q	Losses caused by deductions and restrictions on e-commerce live broadcast platforms for false trading behaviors of merchants in the live broadcast
α	The percentage of e-commerce live broadcast platforms deducting security deposits from live broadcast merchants that adopt non-self-discipline strategies
λ	The third-party supervision body discovers the probability that the live-streaming merchants are selling fakes
x	Probability of live broadcast merchants choosing self-discipline strategy
y	Probability of e-commerce live broadcast platform choosing supervision

strategy is $1 - x$. The probability of e-commerce live broadcast platform supervision strategy is y, $0 \leq y \leq 1$, then the probability of non-supervising strategy is $1 - y$.

- Hypothesis 2 Merchants are required to pay platform usage fees and credit deposits due to entering the e-commerce platform.
- Hypothesis 3 The e-commerce live broadcast platform will be well received by enthusiastic people in the society when it is under supervision, which will bring positive word-of-mouth benefits to the e-commerce live broadcast platform.

2.3 Model Construction

Merchants settled in the live broadcast can randomly and independently choose the "self-discipline" or "non-self-discipline" strategy, and the e-commerce live broadcast platform randomly and independently select the "supervised" or "non-supervised" strategy. Finally, the two parties' strategy choices are as in Table 2.

Table 2. PAYMENT MATRIX OF EVOLUTIONARY GAME MODEL BETWEEN LIVE BROADCAST MERCHANTS AND E-COMMERCE LIVE BROADCAST PLATFORMS

		E-commerce live broadcast platform	
		Regulated	*Not regulated*
Settled merchants	*Self-discipline*	$(W - N_1 - N_2 - C_1,$ $N_1 + N_2 + R_1 - C_3)$	$(W - N_1 - N_2 - C_1,$ $N_1 + N_2 + R_1 - C_6)$
	Not self-disciplined	$(W - N_1 - N_2 - C_2$ $- q - \alpha N_2, N_1 + N_2$ $+ R_1 - C_3 + \alpha N_2)$	$((1-\lambda)(W - N_1 - N_2)$ $+ \lambda(-N_1 - N_2 - C_4)$ $- C_2, (1-\lambda)R_1$ $- \lambda C_5 + N_1 + N_2 - C_6)$

According to the above matrix and copy the dynamic evolution game equation, we can get:

Benefits of live broadcast merchants choosing "self-discipline" strategy: Merchants settled in the live broadcast can randomly and independently choose the "self-discipline" or "non-self-discipline" strategy, and the e-commerce live broadcast platform randomly and independently select the "supervised" or "non-supervised" strategy. Finally, the two parties' strategy choices are as follows.

Benefits of live broadcast merchants choosing "self-discipline" strategy:

$$E_{Z_1} = y(W - N_1 - N_2 - C_1) + (1 - y)(W - N_1 - N_2 - C_1) \tag{1}$$

Benefits of live-streaming merchants who choose the "non-self-discipline" strategy:

$$\begin{aligned} &E_{Z_2} = y(W - N_1 - N_2 - C_2 - q - \alpha N_2) \\ &+(1 - y)[(1 - \lambda)(W - N_1 - N_2) + \lambda(-N_1 - N_2 - C_4) - C_2] \end{aligned} \tag{2}$$

Therefore, the average expected benefits of live broadcast merchants choosing "self-discipline" and "non-self-discipline" strategies are:

$$\begin{aligned} &\overline{E_Z} = xE_{Z_1} + (1 - x)E_{Z_2} = x(W - N_1 - N_2 - C_1) + (1 - x) \\ &\left[y(\lambda(W + C_4) - q - \alpha N_2) + W - N_1 - N_2 - \lambda(W + C_4) - C_2\right] \end{aligned} \tag{3}$$

Commerce live broadcast platform chooses the benefits of the "supervision" strategy:

$$E_{D_1} = x(N_1 + N_2 + R_1 - C_3) + (1 - x)(N_1 + N_2 + R_1 - C_3 + \alpha N_2) \tag{4}$$

The benefits of the e-commerce live broadcast platform choosing the "non-regulation" strategy:

$$\begin{aligned} &E_{D_2} = x(R_1 + N_1 + N_2 - C_6) + \\ &(1 - x)[(1 - \lambda)R_1 - \lambda C_5 + N_1 + N_2 - C_6] \end{aligned} \tag{5}$$

Therefore, the average expected benefits of the e-commerce live broadcast platform choosing the "regulation" and "non-regulation" strategies are:

$$\begin{aligned}\overline{E_D} &= yE_{D_1} + (1-y)E_{D_2} = y(N_1 + N_2 + R_1 - C_3 + \alpha N_2 - \alpha N_2 x) \\ &+(1-y)[x\lambda(R_1 + C_5) + (1-\lambda)R_1 - \lambda C_5 + N_1 + N_2 - C_6]\end{aligned} \tag{6}$$

Derivation order $d\overline{E_Z}/dx = 0$, $d\overline{E_D}/dy = 0$.

There are five equilibrium points in the game between Jiede Live's settled merchants and the e-commerce live broadcast platform:

$$\begin{aligned}&E_1(0,0), E_2(0,1), E_3(1,1), E_4(1,0), \\ &E_5\left(\frac{\alpha N_2 + \lambda(R_1 + C_5) + C_6 - C_3}{\alpha N_2 + \lambda(R_1 + C_5)}, \frac{\lambda(W + C_4) + C_2 - C_1}{\lambda(W + C_4) - q - \alpha N_2}\right)\end{aligned}$$

The dynamic equation for copying live broadcast merchants is:

$$F_Z(x) = \frac{dx}{dt} = x(1-x)\left\{y\left[\lambda(W + C_4) - q - \alpha N_2\right] - \lambda(W + C_4) + C_1 - C_2\right\} \tag{7}$$

The dynamic equation for replication of the e-commerce live broadcast platform is:

$$\begin{aligned}F_D(y) &= \frac{dy}{dt} \\ &= y(1-y)\{-x[\lambda(R_1 + C_5) + \alpha N_2] + \lambda(R_1 + C_5) + \alpha N_2 + C_6 - C_3\}\end{aligned} \tag{8}$$

The Jacobian matrix of the differential system composed of the copy dynamic equation of the live broadcast marketer and the copy dynamic equation of the e-commerce live broadcast platform is:

$$J = \begin{bmatrix} a_{11}, a_{12} \\ a_{21}, a_{22} \end{bmatrix} \tag{9}$$

$$a_{11} = (1-2x)\left\{y\left[\lambda(W + C_4) - q - \alpha N_2\right] - \lambda(W + C_4) + C_1 - C_2\right\} \tag{10}$$

$$a_{12} = x(1-x)\left[\lambda(W + C_4) - q - \alpha N_2\right] \tag{11}$$

$$a_{21} = -y(1-y)[\lambda(R_1 + C_5) + \alpha N_2] \tag{12}$$

$$a_{22} = (1-2y)\{-x[\lambda(R_1 + C_5) + \alpha N_2] + \lambda(R_1 + C_5) + \alpha N_2 + C_6 - C_3\} \tag{13}$$

The determinant of the Jacobian matrix is $\det J$

$$\det J = a_{11}a_{22} - a_{12}a_{21} \tag{14}$$

The trace of the Jacobian matrix is trJ

$$trJ = a_{11} + a_{22} \tag{15}$$

When $x = 0, y = 0$.

$$\det J = [-\lambda(W + C_4) + C_1 - C_2] \bullet [\lambda(R_1 + C_5) + \alpha N_2 + C_6 - C_3],$$

$$trJ = -\lambda(W + C_4) + C_1 - C_2 + \lambda(R_1 + C_5) + \alpha N_2 + C_6 - C_3$$

When $x = 0, y = 1$,

$$\det J = -\left[-q - \alpha N_2 + C_1 - C_2\right] \bullet [\lambda(R_1 + C_5) + \alpha N_2 + C_6 - C_3],$$

$$trJ = -q - \alpha N_2 + C_1 - C_2 - \lambda(R + C_5) - \alpha N_2 + C_3 - C_6$$

When $x = 1, y = 0$,

$$\det J = [-\lambda(W + C_4) + C_1 - C_2] \bullet (C_3 - C_6),$$

$$trJ = \lambda(W + C_4) + C_2 - C_1 - C_3 + C_6$$

When $x = 1, y = 1$,

$$\det J = (q + \alpha N_2 - C_1 + C_2) \bullet (C_3 - C_6),$$

$$trJ = q + \alpha N_2 + C_2 - C_1 + C_3 - C_6$$

3 Analysis of the Stable Point of Evolutionary Equilibrium

1. When $\frac{C_3 - C_6 - \alpha N_2}{R_1 + C_5} < \lambda < \frac{C_1 - C_2}{W + C_4}$, $C_1 - C_2 < q + \alpha N_2$, the system have an evolutionary stable point (0, 1).
2. When $\frac{C_1 - C_2}{W + C_4} < \lambda < 1$, $\frac{C_3 - C_6 - \alpha N_2}{R_1 + C_5} < \lambda < 1$, $C_1 - C_2 < q + \alpha N_2$, the system have an evolutionary stable point (0, 1).
3. When $0 < \lambda < \frac{C_1 - C_2}{W + C_4}$, $0 < \lambda < \frac{C_3 - C_6 - \alpha N_2}{R_1 + C_5}$, $C_1 - C_2 < q + \alpha N_2$, the system have an evolutionary stable point (0, 1).
4. When $0 < \lambda < \frac{C_1 - C_2}{W + C_4}$, $0 < \lambda < \frac{C_3 - C_6 - \alpha N_2}{R_1 + C_5}$, $C_1 - C_2 < q + \alpha N_2$, the system have an evolutionary stable point (1, 0).
5. When $\frac{C_3 - C_6 - \alpha N_2}{R_1 + C_5} < \lambda < \frac{C_1 - C_2}{W + C_4}$, $C_1 - C_2 > q + \alpha N_2$, the system have an evolutionary stable point (1, 0).
6. When $\frac{C_1 - C_2}{W + C_4} < \lambda < 1$, $\frac{C_3 - C_6 - \alpha N_2}{R_1 + C_5} < \lambda < 1$, $C_1 - C_2 > q + \alpha N_2$, the system have no stable point.
7. When $0 < \lambda < \frac{C_1 - C_2}{W + C_4}$, $0 < \lambda < \frac{C_3 - C_6 - \alpha N_2}{R_1 + C_5}$, $C_1 - C_2 > q + \alpha N_2$, the system have an evolutionary stable point (1, 0).
8. When $\frac{C_1 - C_2}{W + C_4} < \lambda < 1$, $0 < \lambda < \frac{C_3 - C_6 - \alpha N_2}{R_1 + C_5}$, $C_1 - C_2 > q + \alpha N_2$, the system have an evolutionary stable point (0, 0).

4 Evolutionary Simulation Numerical Analysis

In order to verify the scientificity and correctness of the above theoretical analysis, explore the evolutionary game process of e-commerce live broadcast platform and live broadcast merchants selling counterfeit with the participation of third-party supervision entities, and the third-party supervision entity discovers that live broadcast merchants sell counterfeit products This section uses Matlab software to further carry out a numerical simulation to simulate the dynamic evolution process of the strategy selection of live broadcast merchants and e-commerce live broadcast platform.

Combining reality and parameter settings, set the initial values of model parameters as follows:

$$W = 7, C_1 = 6, C_2 = 1, C_3 = 8.5, C_4 = 3, C_5 = 5, C_6 = 2, N_2 = 5, R_1 = 5, q = 3, \alpha = 0.7$$

Here are three situations as shown in Fig. 1, Fig. 2, and Fig. 3. Change the percentage of e-commerce live broadcast platforms that deduct deposits from live broadcast merchants that adopt non-self-discipline α, $\alpha = 0.1$. Other parameters remain unchanged, there are three cases of Fig. 4, Fig. 5, and Fig. 6 strategies.

As shown in Figs. 1, 2 and 3, the profit difference between the self-discipline and non-self-discipline strategies selected by the live-streaming merchants is smaller than the loss and credit margin deducted by the e-commerce live streaming platform for the corresponding deductions and restrictions on the false trading behaviors of the live-streaming merchants. When the sum, the third-party supervisory body finds that the probability of selling fake products in the merchants is $0.1 \leq \lambda \leq 0.5$, live broadcast merchants choose a self-discipline strategy, and e-commerce live broadcast platforms choose a non-regulatory strategy; the probability is $0.5 < \lambda \leq 0.9$. The live-streaming merchants choose a non-self-discipline strategy, and the e-commerce live-streaming platform chooses a supervisory strategy.

As shown in Figs. 4, 5 and 6, when the live broadcast merchant chooses the self-discipline and non-self-discipline strategy, the income difference is greater than the loss caused by the deduction and restriction of the rights and the credit margin deducted by the e-commerce live broadcast platform for the false transaction behavior of the

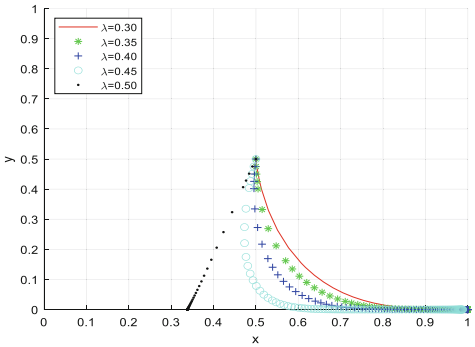

Fig. 1. Situation 1

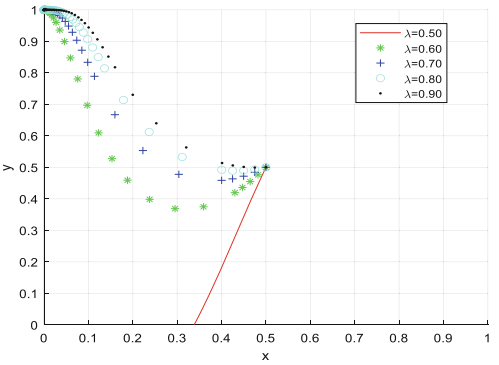

Fig. 2. Situation 2

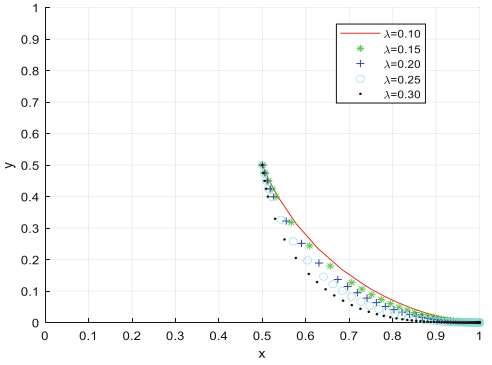

Fig. 3. Situation 3

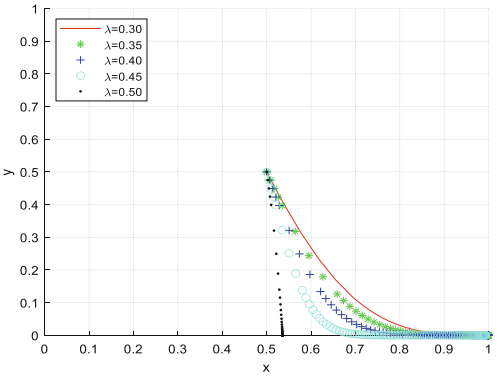

Fig. 4. Situation 5

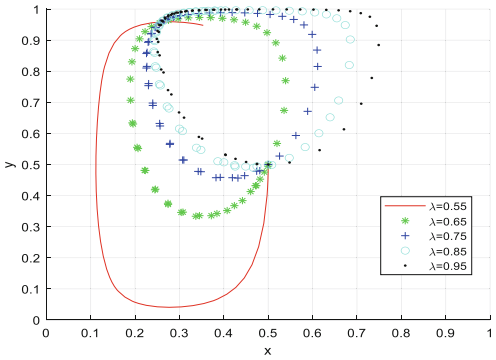

Fig. 5. Situation 6

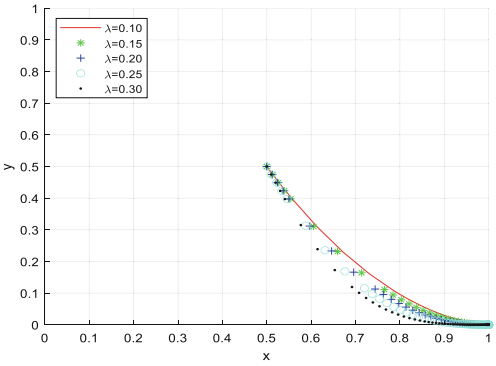

Fig. 6. Situation 7

live broadcast merchant. When the sum, the third-party supervisory body finds that the probability of selling fake products in the merchants is $0.1 \leq \lambda \leq 0.5$, Live broadcast merchants choose a self-discipline strategy, and e-commerce live broadcast platforms choose a non-regulatory strategy; the probability the probability is $0.55 < \lambda \leq 0.95$. System have no stable strategy.

It can be seen from the above that the participation of third-party supervisory bodies will change the strategies of live broadcast merchants and e-commerce live broadcast platforms. When the e-commerce live broadcast platform deducts a low percentage of deposits from live broadcast merchants who adopt undisciplined strategies, the third-party supervisor finds When the probability of a merchant selling fakes is less than the threshold 0.5, the cost of the e-commerce platform choosing not to supervise is lower; and when the third-party monitoring entity finds that the probability of the merchant selling fakes is greater than the threshold 0.5, the e-commerce platform fears the third-party entity and chooses a regulatory strategy. When the e-commerce live broadcast platform have a high percentage of deducting the deposit from the live broadcast merchants that adopt the non-self-discipline strategy, and the third-party supervisory body finds that the probability of the merchant selling fakes is less than the threshold 0.5, the live broadcast

merchants will cost more to sell fakes, so they will choose self-discipline. When the third-party supervision body finds that the probability of the merchant selling fakes is greater than the threshold 0.5, the system have no stable strategy and it is not suitable to choose.

5 Conclusion

Under the condition of bounded rationality, this article builds an asymmetric evolutionary game model for the supervision of e-commerce platforms under the supervision of third-party supervision entities and the sales of fakes by live broadcast merchants. The non-self-disciplined strategy of live broadcast merchants deducting margin, the e-commerce live broadcast platform's corresponding deductions for false transactions of live broadcast merchants and the loss caused by restriction of rights, etc., make the model more convincing. By solving the corresponding replication dynamic equations and the evolutionary stability strategy under various conditions, and drawing the numerical simulation evolution diagram, it intuitively demonstrates the influence of the third-party supervisory body on the strategy choice of both parties, and calculates the probability that the third-party supervisory body finds that the merchant sells fakes Combining with numerical simulation analysis, the validity of the model and its results is demonstrated, and the strategy choices of the two sides of the game under each evolutionary stability strategy are explained in detail, which provides ideas for the effective solution of the problem of counterfeit sales by live broadcast merchants.

Through the evolutionary game analysis, it is found that the participation of third-party supervisors can affect the strategy choices of e-commerce live broadcast platforms and live broadcast merchants. When third-party supervisors find that the probability of merchants selling fakes is low, it is beneficial for merchants to choose self-discipline strategies. When the main body of supervision finds that the merchants have a high probability of selling fakes, it is helpful to supervise the e-commerce live broadcast platform's supervision of the live broadcast merchants. The intervention of a third-party supervisory body is an important breakthrough to solve the problem of live-streaming counterfeit sales. On the one hand, the government, as a third-party supervisory agency trusted by consumers, can increase consumers' trust in the live-streaming shopping environment, thereby increasing consumers' willingness to buy. Promote the benign interaction among live broadcast merchants, e-commerce live broadcast platforms, and consumers. On the other hand, third-party supervisors need to control the probability and frequency of supervision, focus on cracking down on the sale of fake live broadcasts, and purify the live broadcast environment.

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