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Research Article

Evolutionary Game Analysis of Consumer Complaint Handling in E-Commerce

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Untimely complaint handling can affect the reputation of the e-commerce platform and lead to customer loss, which is not conducive to the sustainable development of the e-commerce industry. To address the problem of untimely handling of consumer complaints, based on the evolutionary game theory, the e-commerce dispute mediation platform is introduced, the authenticity of consumer complaints and the probability of e-commerce platform to be in the mediation platform are considered, a tripartite evolutionary game model of consumer-mediation platform-e-commerce platform is constructed, and the problem of which strategy the mediation platform and e-commerce platform choose to handle consumer complaints is studied. Numerical simulation and simulation analysis are conducted using MATLAB 2020b, and corresponding suggestions are given. The research results show that under certain conditions when the probability of mediation platform and e-commerce platform positively handling complaint increases or the penalty for consumer distortion complaint increases; when the probability of consumer's real complaint increases, the probability of mediation platform positively handling complaint increases; the consumer tend to choose real complaint, the mediation platform tends to choose positively handling strategy, the e-commerce platform positively enters the mediation platform, the mediation platform and consumer's behavior to the reputation of the e-commerce platform increases, which can promote the e-commerce platform to positively handle the consumer complaint.

1. Introduction

The main e-commerce dispute mediation platforms are Electric Complaint Treasure and Black Cat Complaint in China. Up to now, Electric Complaint Treasure has accepted more than 100,000 complaints, affecting more than 100 million users. Black Cat Complaint has accumulated more than 5.9 million effective complaints. However, the problem of untimely processing of complaints is still serious, and some consumers' complaints are handled very inefficiently or even some long time after the problem has not been handled. This leads to consumer dissatisfaction with the e-commerce platform, reduces consumers' trust in the e-commerce platform, affects the mediation platform and the reputation of the e-commerce platform, thus affecting the sustainable development of the entire e-commerce industry. In this context, the study of consumer complaint handling strategies can better coordinate disputes between

consumers and the complained e-commerce platform/ sellers, better solve after-sale problems, safeguard the legitimate rights and interests of consumers, enhance consumer satisfaction with the services of the e-commerce platform, improve the reputation of the e-commerce platform, build a harmonious e-commerce business-consumer relationship, and promote the healthy and sustainable development of the e-commerce industry.

Electric complaint treasure and black cat complaint platform have realized a key complaint, 24 h online, self-help rights, synchronization direct, real-time processing, progress inquiry, evaluation system, legal help, big data analysis, and many other functions. According to the data of Electric Complaint, there are more complaints about retail e-commerce, life service e-commerce, online travel, online education, and online takeaway in 2020, among which, retail e-commerce complaints account for more than half of the total complaints. The hot issues of complaints are refund

problems, quality of goods, delivery problems, network fraud, after-sales service, network sales counterfeit, bullying terms, false promotion, difficulty to return and exchange goods, order problems, goods are not right, logistics problems, etc.

The emergence of e-commerce dispute mediation platforms, which are third-party complaint handling organizations that coordinate disputes, resolve disputes, and provide specific assistance to individual or collective complainants, has brought significant changes to the entire e-commerce industry. The data from the Electric Complaint and Black Cat complaint platforms shows that consumers' awareness of their rights is getting stronger and stronger [1], and the voice from consumers is gradually becoming an important factor in the market [2], and consumer complaints are contributing more and more to the sustainable development of the entire e-commerce industry. Consumer complaining is a series of possible responses to an unsatisfactory consumer situation [3–6]. When consumers encounter an unsatisfactory shopping experience, they are likely to express their dissatisfaction by filing a complaint [7]. Online complaint behavior is punitive, affecting the public perception of a business and damaging the image of a platform or company's reputation [7–9]. Poorly handled complaints also may lead to customer loss [10]. Consumer complaints play an indirect regulatory role for online sellers and help companies to better improve their services [11, 12]. Satisfaction with complaint handling also affects the corporate image and reputation [13, 14], and effective complaint handling also has a considerable chance of winning back the complaining consumers [15–17].

Currently, domestic and foreign scholars have studied the issue of consumer complaints from different aspects, and in the existing literature on consumer complaints, most of them are still dominated by empirical studies [18–26]. Boote [27] developed a two-factor taxonomy of consumer complaint behavior, classifying complaints according to whether they are primary or secondary, involved or uninvolved; and constructed a model of consumer complaint behavior that divides the entire consumer complaint behavior into four processes: rational reasoning, affective response, triggering of consumer dissatisfaction response, and effective action. Brennan et al. [28] consider consumer vulnerability and complaint handling organizations and examine new models of consumer dispute system design and the operation of complaint handling organizations. Lu et al. [29] developed a four-dimensional scale of consumer complaints and recovery efforts, which consists of procedural, cognitive, temporal, and affective components. Bastani et al. [30] extracted thematic and temporal trends in complaints and proposed an intelligent method based on Latent Dirichlet Allocation (LDA) to analyze consumer complaints in the Consumer Financial Protection Bureau.

In addition, studies on the handling of consumer complaints have focused on their impact on corporate reputation. Fast and effective handling of consumer complaints can improve the organization's reputation to some extent. Einwiller and Steilen [14] analyzed how large companies handle their complaints on Facebook and Twitter by applying content, and the study showed that public complaints can damage the organization's reputation, but effective handling of complaints can demonstrate the organization's ability and willingness to solve problems, which may improve its reputation. Istanbulluoglu [15] considered the response time of consumer complaints and showed that both faster first response and faster conclusive response increase consumer satisfaction with complaint handling and that negative complaint handling can lead to loss of existing customers, shape negative word of mouth, and negatively affect the company's reputation. Johnen and Schnittka [10] introduced an observer's perspective under hedonism and utilitarianism, using the reason for the complaint as a condition, and the study showed that under certain conditions complainants and observers of the brand's communication on social media may be more inclined to respond defensively rather than accommodatingly. Researchers mostly study the impact of untimely handling of consumer complaints on the reputation of enterprises or organizations empirically, and fewer scholars introduce consumer complaints into the model to study the problem of consumer complaint handling.

In recent years, the simple two-party evolutionary game is no longer enough to satisfy scholars' research, and most scholars study the stability strategies of game subjects under different models [31–37], or the evolutionary game problems involving three or even four parties. Zhang et al. [38] considered the outsourcing model and the licensing model, and constructed a competitive closed-loop supply chain consisting of two original equipment manufacturers and two third-party remanufacturers. Chen and Hu [33] examine the behavioral strategies of both suppliers and governments under various combinations of carbon taxes and subsidies. Sun et al. [39] developed a two-sided evolutionary game-theoretic model of suppliers and manufacturers under the government subsidy mechanism to study the optimal green investment strategy under the government subsidy policy. Feng et al. [40] introduced a public oversight mechanism (two regulators and one regulated) and developed a model based on multiplayer evolutionary games and system dynamics. Ma and Zhang [41] constructed a two-sided dynamic evolutionary game model consisting of construction firms and recycling firms with and without government incentives to study the construction waste recycling management problem. Liu et al. [42] construct a tripartite evolutionary game model of the State Coal Mine Safety Supervision Bureau, local coal mine safety supervision departments, and coal enterprises, and use dynamic penalty control and penalty-incentive to control fluctuations to study the coal mine safety supervision problem in China. Kang et al. [43] studied a two-level supply chain consisting of retailers and manufacturers, and used the Stackelberg game to solve the low-carbon strategy combinations of four retailers and manufacturers, and then used the evolutionary game for further analysis, examining the choice of a competitive closed-loop supply chain third-party remanufacturing model. Sheng et al. [44] constructed a tripartite game model of the national government, local government, and enterprises to study incentive-compatible

environmental regulatory policies. In the existing literature on consumer complaints, traditional evolutionary game theory has mostly been applied to study regulatory problems, but generally, consumer complaints are introduced into the model as parameters. He and Zhu [11] introduced consumer feedback into a three-way evolutionary game involving government regulators, sellers, and the e-commerce platform, and found that consumer complaints can indirectly regulate sellers and influence the choice of the e-commerce platform through fines imposed on them by government regulators. Fewer scholars have used the evolutionary game theory approach to study the problem of consumer complaint handling. As the e-commerce model is evolving, the complaint handling system is improving, consumers' awareness of their rights is increasing, and the interests of relevant subjects are changing. Evolutionary game theory can provide help for the strategy selection of consumer complaint handling subjects.

In summary, a review of the literature reveals that most of the theoretical research on consumer complaint handling has been conducted empirically to study the impact of consumer complaint handling on enterprises, but there is a lack of research and analysis on consumer complaint handling by consumers, mediation platforms and the e-commerce platform. There are also fewer studies that use evolutionary game theory to study consumer complaint handling.

Therefore, this study aims to address the following questions.

(1) What complaint strategies consumers should choose under what conditions?

(2) What consumer complaint handling strategies should be chosen by the e-commerce platform and mediation platforms under what conditions?

(3) What measures should be taken by consumers, mediation platforms, and the e-commerce platform in the future to promote the positive, healthy, and sustainable development of the entire e-commerce industry?

In summary, this paper differs from other scholars' studies in that: firstly, the e-commerce dispute mediation platform was introduced according to the actual situation, while considering the authenticity of consumer complaints and the probability of the e-commerce platform being in the mediation platform are considered, a tripartite evolutionary game model with consumers, the mediation platform and the e-commerce platform as the main players are constructed. Secondly, the stability of the three-game subjects is analyzed, as well as the effects of factors such as e occupancy rate, processing cost, penalty, and impact on reputation, and the stability of pure strategy combinations are analyzed based on Lyapunov's first law. Finally, numerical simulation through MATLAB 2020b, the effect of the probability of the e-commerce platform being enrolled in the mediation platform, the probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively, impact of factors leading to the loss of

e-commerce platform reputation on the choice of e-commerce platform strategy on the strategy choice of the game subjects were analyzed.

2. Materials and Methods

In this section, the problems under study are described in detail, the assumptions used, specific notational descriptions are depicted, and the tripartite game payment matrix is presented.

The e-commerce dispute mediation platform was introduced, and the issue of consumer complaint handling was studied with the process shown in Figure 1. The consumer makes a complaint in the e-commerce dispute mediation platform; the mediation platform reviews the consumer's complaint and docks with the e-commerce platform to transfer the consumer's complaint; the e-commerce platform accepts the complaint information transferred by the mediation platform and negotiates with the consumer for compensation.

The consumer can make a one-click complaint in the mediation platform system and check the progress of the complaint processing at any time. For those the e-commerce platform that is not part of the mediation platform, the mediation platform staff will contact them directly and actively promote the e-commerce platform or merchants to solve the problem complained by the consumer. After the e-commerce platform has been stationed in the mediation platform, the e-commerce platform logo entrance can be linked in a prominent position in the mediation platform, and there is a dedicated person through the microblogging, mediation platform system and another docking, enjoy the privilege of priority review, transfer distribution, and at any time can view real-time data, lists, rankings, ratings, etc. The mediation platform will also use the relying media to promote the resident e-commerce platform, etc. The publicity service of the mediation platform has increased the reputation of the settled e-commerce platform, which is set as G. After the complaint processing is completed, the consumer can evaluate the satisfaction of the e-commerce platform's processing. When the e-commerce platform is negatively handled, the probability that consumers are not satisfied with the processing results of the e-commerce platform is set to β. The mediation platform supervises the behavior of the consumer and the e-commerce platform, exposes the mistakes according to the real complaint and the feedback of the complained e-commerce company, and ranks, rates, and writes data analysis reports on the e-commerce platform according to the data collected by the mediation platform. Therefore, the positive evaluation of the mediation platform has increased the reputation of the e-commerce platform N_1 and the reputation loss of the e-commerce platform caused by negative reports of the mediation platform is N_2.

The tripartite evolutionary game model with the consumer, mediation platform, and e-commerce platform as the main players is constructed. The assumptions are as follows.

Assumption 1. The probability of consumer's real complaint is p and the probability of distorted complaint is $1 - p$; the probability of mediation platform's positive handling and
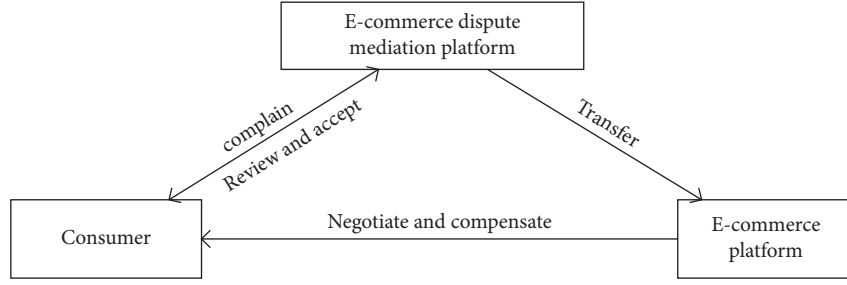
FIGURE 1: Flow chart of multisubject complaint processing.

the probability of negative handling is $1 - q$; the probability of e-commerce platform's positive handling and the probability of negative handling is $1 - g$. $p, q, g \in [0, 1]$. All three parties are finite rational and keep adjusting their strategy choices over time according to the benefit maximization principle.

Assumption 2. When a consumer's complaint is judged to be a distorted complaint, the mediation platform rejects the relevant complaint order, bans the relevant offending complaint account in serious cases, and the complainant may also bear certain legal responsibilities. Therefore, set the penalty of consumer distortion complaint as S.

Assumption 3. The probability of the e-commerce platform settling in the mediation platform is α. The settlement of e-commerce platform in the mediation platform will pay a certain fee, which is set to V. The resident e-commerce platform enjoys the privilege of prioritizing the review, handing over distribution, and assisting customers in dealing with after-sales matters, and the mediation platform will not deal with it negatively.

Assumption 4. When the mediation platform is negatively handled, the nonresident e-commerce platform can contact the mediation platform and submit corresponding evidence when it finds distortion complaints in the process of handling complaints, and the mediation platform will verify and

handle them accordingly according to the rules. The nonsettled e-commerce platform that positively handles consumer complaints proves that the cost of consumer distortion complaints is Q_1. The nonsettled e-commerce platform that negatively handles consumer complaints proves that the cost of consumer distortion complaints is Q_2.

The specific symbols and descriptions are listed in Table 1.

Table 2 shows the payoff matrix constructed for the tripartite game between consumer, mediation platform, and e-commerce platform.

3. Results of Stability Analysis of Each Game Subject's Strategy

To determine the consumer complaint handling strategy, this section will analyze the evolutionary game from the perspective of consumers, mediation platforms, the e-commerce platform, and strategy combinations, respectively. In addition, the influence of relevant parameters on the evolutionary process will be analyzed.

3.1. Stability Analysis of Consumer's Complaint Strategies. The expected benefits of consumer who chooses to make a real complaint or distortion complaint, and the replicated dynamic equation and the first derivative of the complaint strategy are, respectively:

$$
\begin{cases}
\pi_p = qg(-C_1 + A_1) + (1-q)g(-C_1 + A - U_1) + q(1-g)(A - \beta J - C_1 - U_1) \\
\quad + (1-q)(1-g)(A - \beta J - C_1 - J - U_1 - U_2) \\
\pi_{1-p} = qg(-C_2 - S) + (1-q)g(-C_2 - S - U_1) + q(1-g)(-C_2 - S - U_1) \\
\quad + (1-q)(1-g)(-C_2 - S - U_1 - U_2)
\end{cases}
,
$$

$$
F(p) = \frac{dp}{dt}
$$

$$
= p(1-p)(-J + gJ + Jq - gJq + S - J\beta + gJ\beta + A - C_1 + C_2),
$$

$$
F'(p) = (1-2p)(-J + gJ + Jq - gJq + S - J\beta + gJ\beta + A - C_1 + C_2).
$$

(1)

Table 1: Summary of notations.

Symbols	Meaning and description
C1	Real complaint cost of consumer
T1	Positive handling cost of a mediation platform
L1	Positive handling cost of e-commerce platform
U1	Consumer waiting cost when the mediation platform is handled negatively
M	Mediation platform operating cost
Y	Other benefits of a mediation platform
A	Compensation to the consumers by e-commerce platform (A > C1 > C2)
X1	The increased reputation of the e-commerce platform due to consumer's satisfaction with the result of processing
L0	Handling costs by the e-commerce platform that have been enrolled
D1	Increased reputation due to positive handling of a real complaint by mediation platform
C2	Distortion complaint cost of consumer
T2	Negative handling cost of a mediation platform (T1 > T2)
L2	Negative handling cost of an e-commerce platform (L1 > L2)
U2	Consumer waiting cost when the e-commerce platform is handled negatively
F	Mediation platform service cost for the resident platform
B	Other benefits of e-commerce platform
J	Loss caused by consumer's dissatisfaction with the result of a complaint
X2	Loss of reputation of e-commerce platform lost due to consumer's dissatisfaction with the result of processing
Z	Loss of reputation of e-commerce platform due to the consumer's complaint
D2	Loss of reputation of the mediation platform due to negative handling of a real complaint by the mediation platform

Proposition 1. *Under* $0 \le q_0 \le 1, 0 \le g_0 \le 1$, *when* $q > q_0$, $g > g_0$, *the consumer's stability strategy is true complaint; when* $q < q_0$, $g < g_0$, *the consumer's stability strategy is distorted complaint; when* $q = q_0$, $g = g_0$, *the consumer's stability strategy is uncertain, where the threshold is* $q_0 = 1 - S - (1 - g)J\beta + A - C_1 + C_2/(1 - g)J$, $g_0 = 1 - S + A - C_1 + C_2/J(1 - q + \beta)$.

See Appendix A for the specific certification process.

Proposition 1 shows that under certain conditions, the probability of the consumer's true complaint increases with the probability of positive handling by the mediation platform and the probability of positive handling by the e-commerce platform. Both the mediation platforms and the e-commerce platform positively handle consumers' complaints, which can increase the rate of true consumers' complaints and thus provide better after-sales service to consumers.

The phase diagram of consumer strategy choice is shown in Figure 2.

Let the probability of consumer's real complaint is V_{P1}, the probability of consumer's distortion complaint is V_{P2}. Let $i = A + S - C_1 + C_2/(1 - g)J(1 + \beta)$. , $V_{p2} = \int_0^1 \int_0^{1 - S - (1-g)J\beta + A - C_1 + C_2/(1-g)J}$ $[1 - S + A - C_1 + C_2/J(1 - q + \beta)]\mathrm{d}q\mathrm{d}p = \ln i(A + S - C_1 + C_2)/J$ $V_{p1} = 1 - \ln i(A + S - C_1 + C_2)/J$

Corollary 1. *Under* $i \langle 1/e$, *the consumer tends to choose the real complaint strategy when the penalty for consumer distortion complaint is higher or real complaint cost of the consumer is lower or distortion complaint cost of the consumer is higher.*

Corollary 2. *When* $S + A - C_1 + C_2 \langle 0$, *the higher the loss caused by consumers' dissatisfaction with the complaint result or the lower the probability of consumers being dissatisfied with the outcome when the e-commerce platform is handled negatively, the consumer tends to choose the real complaint*

strategy. When $S + A - C_1 + C_2 \rangle 0$, *the higher the loss caused by consumer's dissatisfaction with the result of a complaint or the higher the probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively, the consumer tends to choose the distortion complaint strategy. When* $S + A - C_1 + C_2 = 0$, *the loss caused by consumers' dissatisfaction with the complaint result and the probability of consumers being dissatisfied with the outcome when the e-commerce platform is handled negatively do not affect the choice of consumer's complaint strategy.*

See Appendix A for the specific certification process.

3.2. Stability Analysis of Mediation Platform's Complaint Handling Strategies.

The expected benefits of mediation platform who chooses to make positive handling or negative handling, and the replicated dynamic equation and the first derivative of the complaint strategy are, respectively:

$$\begin{cases} \pi_q = p[\alpha(V - F) - (1 - \alpha)T_1 - M + Y + D_1] \\ \quad + (1 - p)[\alpha(V - F) - (1 - \alpha)T_1 - M + Y] \\ \pi_{1-q} = p[\alpha(V - F + D_1) - (1 - \alpha)(T_2 + D_2) - M + Y] \\ \quad + (1 - p)[\alpha(V - F) - (1 - \alpha)T_2 - M + Y] \end{cases},$$

$$F(q) = \frac{\mathrm{d}q}{\mathrm{d}t}$$

$$= q(1 - q)\{(1 - \alpha)[p(D_1 + D_2) - T_1 + T_2]\},$$

$$F'(q) = (1 - 2q)\{(1 - \alpha)[p(D_1 + D_2) - T_1 + T_2]\}.$$

(2)

TABLE 2: Tripartite game payoff matrix.

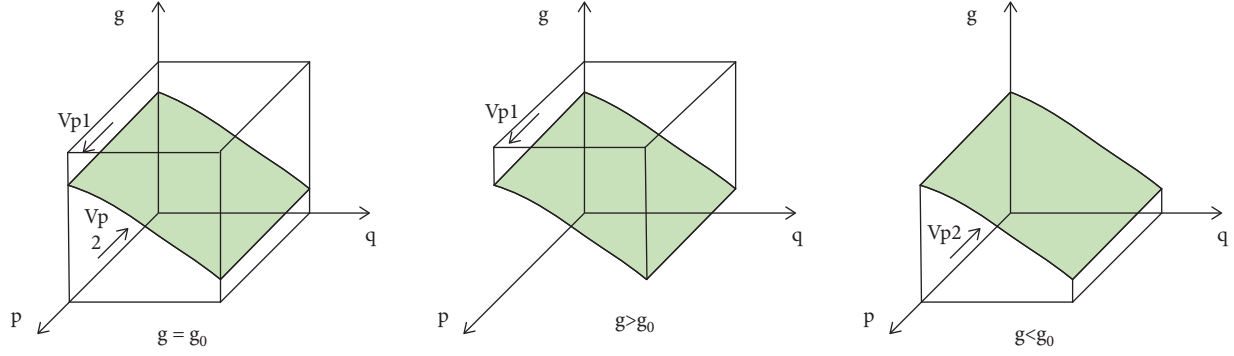| | | E-commerce dispute mediation platform | | |
		Positive handling q	Negative handling $1-q$	
Consumer	Real complaint p	$\{-C_1t + nAq, ha, (V - F)x - 7(1 - \alpha)CT_1 - M + Y + D_1, \alpha(G - V - L_0) - (1 - \alpha)L_1t + nN_1q - hZ, xA7 + CB, +X_1\}$	$\{-C_1t + nAq, ha, xa\overline{\alpha}(V - F + D_1)C - (1 - \alpha)*(T_2 + D_2) - M + Y, \alpha(G - V - L_0) - (1 - \alpha)L_1 + N_1, - Zt - nAq + hB, xX_1\}$	Positive handling g
	Distortion complaint $1-p$	$\{-C_2t - nSq, ha, (V - F)x - 7(1 - \alpha)CT_1 - Mt + nYq, ha, (G - V)x + 7B\}$	$\{-C_2t - nSq - hU_1, xa7(V - F)C - (1 - \alpha)T_2 - M + Y, \alpha(G - V) + Bt - n(1 - \alpha)qQ_1\}$	
	Real complaint p	$[A - t\beta nIq - hC_1, xU_17, Ca; (V - F) - (1 - \alpha)T_1 - M + Y + D_1, \alpha(G - V - L_0) - (1 - \alpha)L_2 - N_2 - Zt - nAq - h\beta X_2x + 7(1 - \beta)CX_1, +B]$	$[A - t\beta nIq - hC, xI7 - CU_1; -U_2, \alpha(V - F + D_1) - (1 - \alpha)(T_2 + D_2) - M + Y, \alpha(G - V - L_0) - (1 - \alpha)L_2 - N_2 - Z - A - \beta X_2 + (1 - \beta)t*nX_1q + hB]$	Negative handling $1-g$
	Distortion complaint $1-p$		$\{-C_2t - nSq - hU_1, xU_17, Ca; (V - F) - (1 - \alpha)T_2 - M + Y, \alpha(G - V) + B - t(1 - \alpha)nQ_2\}$	
				E-commerce platform

FIGURE 2: Phase diagram of consumer strategy choice.

Proposition 2. *When $\alpha = 1$, mediation platform selects complaint handling strategy uncertainty. Under $0 \leq p_1 \leq 1$, when $p \rangle p_1$, mediation platform stabilizes the choice of positive handling strategy; when $p < p_1$, mediation platform stabilizes the choice of negative handling strategy; when $p = p_1$, uncertainty in the choice of complaint handling strategy by the mediation platform. Where the threshold is $p_1 = (T_1 - T_2)/(D_1 + D_2)$.*

See Appendix A for the specific certification process.

Proposition 2. *shows that under certain conditions, the probability of the mediation platform positively handling the consumer complaint increases with the probability of the real consumer complaint.*

The mediation platform strategy selection phase diagram is shown in Figure 3.

Let the probability of the mediation platform being positive and the probability of the mediation platform being negative be. $V_{p2} = \int_0^1 \int_0^{T_1 - T_2/D_1 + D_2} (T_1 - T_2/D_1 + D_2) dg dq = (T_1 - T_2)^2/(D_1 + D_2)^2$, $V_{p1} = 1 - V_{p2} = 1 - (T_1 - T_2)^2/(D_1 + D_2)^2$.

Corollary 3. *The probability that the mediation platform chooses to deal actively increases with the increase of*

reputation caused by its active handling of real complaints and the increase of reputation loss caused by its passive handling of real complaints.

See Appendix A for the specific certification process.

Corollary 4. *When the positive handling cost of the mediation platform decreases or the negative handling cost of the mediation platform increases, under $D_1 - (1 - g)(1 - \alpha)(T_1 - T_2)\rangle 0$, $0 \leq g[D_2 - (1 - \alpha)(T_1 - T_2)]/ - D_1 + (1 - g)(1 - \alpha)(T_1 - T_2) \leq 1$, when $D_1 - (1 - g)D_2 > 0$, mediation platform stabilizes the choice of positive handling strategy; when $D_1 - (1 - g)D_2 \rangle 0$, mediation platform stabilizes the choice of negative handling strategy. Under $D_1 - (1 - g)(1 - \alpha)(T_1 - T_2)\langle 0$, $0 \leq g[D_2 - (1 - \alpha)(T_1 - T_2)]/ - D_1 + (1 - g)(1 - \alpha)(T_1 - T_2) \leq 1$, it's the opposite.*

See Appendix A for the specific certification process.

3.3. Stability Analysis of E-Commerce Platform's Complaint Handling Strategies.
The expected benefits of an e-commerce platform that chooses to make positive handling or negative handling, and the replicated dynamic equation and the first derivative of the complaint strategy are, respectively:

$$
\begin{cases}
\pi_g = p\left[\alpha(G - V - L_0) - (1 - \alpha)L_1 + N_1 - Z - A + B + X_1\right] + (1 - p)q\left[\alpha(G - V) + B\right] \\[2mm]
+ (1 - p)(1 - q)\left[\alpha(G - V) + B - (1 - \alpha)Q_1\right] \\[2mm]
\pi_{1-g} = p\left[\alpha(G - V - L_0) - (1 - \alpha)L_2 - N_2 - Z - A - \beta X_2 + (1 - \beta)X_1 + B\right] \\[2mm]
+ (1 - p)q\left[\alpha(G - V) + B\right] + (1 - p)(1 - q)\left[\alpha(G - V) + B - (1 - \alpha)Q_2\right]
\end{cases}
\tag{3}
$$

$$
F(g) = \frac{dg}{dt}
$$

$$
= g(1 - g)\{p[(1 - \alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2] + (1 - p)(1 - q)(1 - \alpha)(Q_2 - Q_1)\},
$$

$$
F'(g) = (1 - 2g)\{p[(1 - \alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2] + (1 - p)(1 - q)(1 - \alpha)(Q_2 - Q_1)\}.
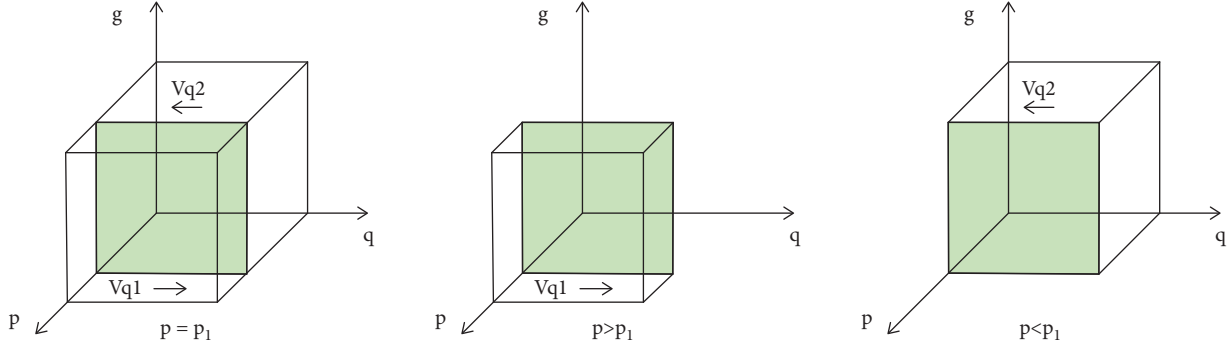$$

Figure 3: Phase diagram of mediation platform strategy selection.

Let $a = (1 - \alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2$, $b = (1 - \alpha)(Q_1 - Q_2)$

Proposition 3. *Under and , when and , stable choice of positive handling strategy for e-commerce platform. When $p \langle p_2$ and $q \langle q_2$, stable choice of negative handling strategy for e-commerce platform. Where the threshold is $p_2 = 1 - a/a + (1 - q)b$, $q_2 = 1 - pa/(1 - p)b$.*

See Appendix A for the specific certification process.

Proposition 3 shows that under certain conditions, the probability of the e-commerce platform choosing to actively handle increases with the increase of the probability of consumers' real complaints and the probability of mediation platforms actively handling. The more real consumer complaints are, that is, the more real problems appear on the e-commerce platform, and the more active the e-commerce platform will handle consumer complaints. The mediation platform chooses to actively deal with consumer complaints. At this time, complaints accumulate on the e-commerce platform. In order not to stop the complaint processing progress on the e-commerce platform and damage the reputation of the e-commerce platform, the e-commerce platform will choose to actively deal with them.

The phase diagram of e-commerce platform strategy choice is shown in Figure 4.

Let the probability of e-commerce platform's positive handling is V_{g1}, the probability of e-commerce platform's negative handling is V_{g2}.

$$V_{g2} = \int_0^1 \int_0^{1-pa/(1-p)b} \int_0^1 \left[1 - \frac{a}{a + (1 - q)b} \right] dq dg = 1 + \frac{a\{p + (1 - p)\ln[a/(a + b)(1 - p)]\}}{b(1 - p)},$$

$$V_{g1} = 1 - V_{g2} = \frac{-a\{p + (1 - p)\ln[a/(a + b)(1 - p)]\}}{b(1 - p)}.$$

(4)

Corollary 5. *Under $0 \leq a/[a + (1 - q)b] \leq 1$, There are several ways to increase the probability of the e-commerce platform choosing a positive handling strategy: increased probability of e-commerce platform being enrolled in mediation platforms; decreased negative handling cost of e-commerce platform; increased cost of negatively handling consumer complaints; decreased Cost paid by e-commerce platform that actively handle complaint to prove consumer distortion complaint; raised increased reputation of e-commerce platform due to consumer's satisfaction with the result of processing; increased loss of reputation of e-commerce platform lost due to consumer's dissatisfaction with the result of processing; increased loss of reputation of the mediation platform due to negative handling of genuine complaints by the mediation platform; increased cost paid by the e-commerce platform proving consumer distortion complaints by the negative handling of complaints; enlarged increased reputation of e-commerce platform due to positive evaluation of mediation platform.; increased loss of reputation of the e-commerce platform due to negative reports on the mediation platform; probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively.*

See Appendix A for the specific certification process.

3.4. Stability Analysis of Strategy Portfolio. In the replicated dynamic system, the stability of the strategy combinations of the tripartite game subjects, the consumer, mediation platform, an e-commerce platform, can be judged according to Lyapunov's first law. The stability of eight pure strategy equilibrium points in the tripartite evolutionary game is analyzed in Table 3. The Jacobi matrix is obtained from the replicated dynamic equations of each game subject.
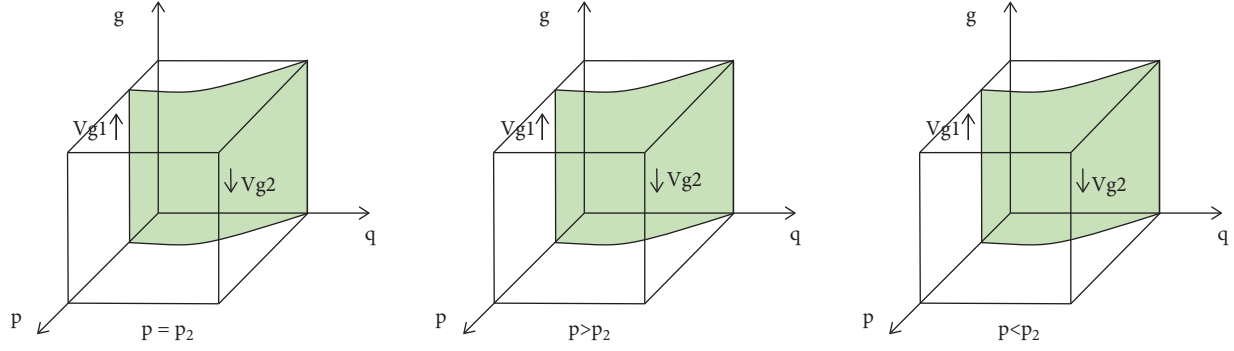
FIGURE 4: Phase diagram of e-commerce platform strategy selection.

TABLE 3: Replicated dynamic system equilibrium point asymptotic stability analysis.

Equilibrium point	Eigenvalue	Eigenvalue symbols	Stability
$(0,0,0)$	$\{-(1-\alpha)(Q_1 - Q_2), -(1-\alpha)(T_1 - T_2), A - C_1 + C_2 - J + S - J\beta\}$	$-,-,\times$	ESS when condition a is satisfied
$(0,1,0)$	$\{0, (1-\alpha)(T_1 - T_2), A - C_1 + C_2 + S - J\beta\}$	$0,+,\times$	Unstable
$(0,0,1)$	$\{(1-\alpha)(Q_1 - Q_2), -(1-\alpha)(T_1 - T_2), A - C_1 + C_2 + S\}$	$+,-,\times$	Unstable
$(0,1,1)$	$\{0, (1-\alpha)(T_1 - T_2), A - C_1 + C_2 + S\}$	$0,+,\times$	Unstable
$(1,1,1)$	$\{C_1 - C_2 - A - S, -[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2], (1-\alpha)[-(D_1 + D_2) + T_1 - T_2]\}$	$-,-,\times$	ESS when condition b is satisfied
$(1,1,0)$	$\{C_1 - C_2 - A - S + J\beta, (1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2, -(1-\alpha)(D_1 + D_2 - T_1 + T_2)\}$	$\times,+,\times$	Unstable
$(1,0,1)$	$\{C_1 - C_2 - A - S, -[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2], (1-\alpha)(D_1 + D_2 - T_1 + T_2)\}$	$-,-,\times$	ESS when condition c is satisfied
$(1,0,0)$	$\{C_1 - C_2 - A + J - S + J\beta, (1-\alpha)(D_1 + D_2 - T_1 + T_2), (1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2\}$	$\times,\times,+$	Unstable

1 Condition a : $A - C_1 + C_2 - J + S - J\beta \langle 0$; Condition b : $-D_1 - D_2 + T_1 - T_2 \langle 0$; Condition c : $D_1 + D_2 - T_1 + T_2 \langle 0$.

$$J = \begin{bmatrix} \dfrac{\partial F(p)}{\partial p} & \dfrac{\partial F(p)}{\partial q} & \dfrac{\partial F(p)}{\partial g} \\[2mm] \dfrac{\partial F(q)}{\partial p} & \dfrac{\partial F(q)}{\partial q} & \dfrac{\partial F(q)}{\partial g} \\[2mm] \dfrac{\partial F(g)}{\partial p} & \dfrac{\partial F(g)}{\partial q} & \dfrac{\partial F(g)}{\partial g} \end{bmatrix}. \tag{5}$$

Here, $\partial F(p)/\partial p = (1-2p)(-J + gJ + Jq - gJq + S - J\beta + gJ\beta + A - C_1 + C_2)$, $\partial F(p)/\partial q = p(1-p)(1-g)J$, $\partial F(p)/\partial g = p(1-p)(1-q+\beta)J$, $\partial F(q)/\partial p = q(1-q)(1-\alpha)(D_1 + D_2)$, $\partial F(q)/\partial q = (1-2q)(1-\alpha)[p(D_1 + D_2) - T_1 + T_2]$, $\partial F(q)/\partial g = 0$, $\partial F(g)/\partial p = g(1-g)[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + (1-q)(1-\alpha)(Q_1 - Q_2) + \beta X_1 + \beta X_2]$, $\partial F(g)/\partial q = g(1-g)(1-p)(1-\alpha)(Q_1 - Q_2)$, and $\partial F(g)/\partial g = (1-2g)\{p[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta(X_1 + X_2)] + (1-p)(1-q)(1-\alpha)(Q_2 - Q_1)\}$

As can be seen from Table 3, there is only one stable point (0,0,0) when the condition a is satisfied, so to avoid consumer distortion complaints, mediation platform negative treatment, e-commerce platform negative treatment to become a stable strategy combination, to increase the penalty for distortion complaints, enhance consumer awareness of their rights, at least should satisfy $S \geq -A + J + J\beta + C_1 - C_2$ or $0 \langle J \leq 1/2(A + S - C_1 + C_2) \& 0 \leq \beta \leq 1$ or $1/2(A + S - C_1 + C_2) \langle J \langle A + S - C_1 + C_2 \& 0 \leq \beta \leq (A - J + S - C_1 + C_2)/J$ or $J = A + S - C_1 + C_2 \& \beta = 0$. When condition b is satisfied, there is only one stable point (1, 1, 1), i.e., consumers' real complaints, the mediation platform's positive handling, and the e-commerce platform's positive handling become a stable strategy combination. When condition c is satisfied, there is only one stable point (1, 0, 1), to avoid the real consumer complaint, mediation platform negative handling, e-commerce platform positive handling become a stable strategy combination, should improve the credibility and influence of mediation platform to the
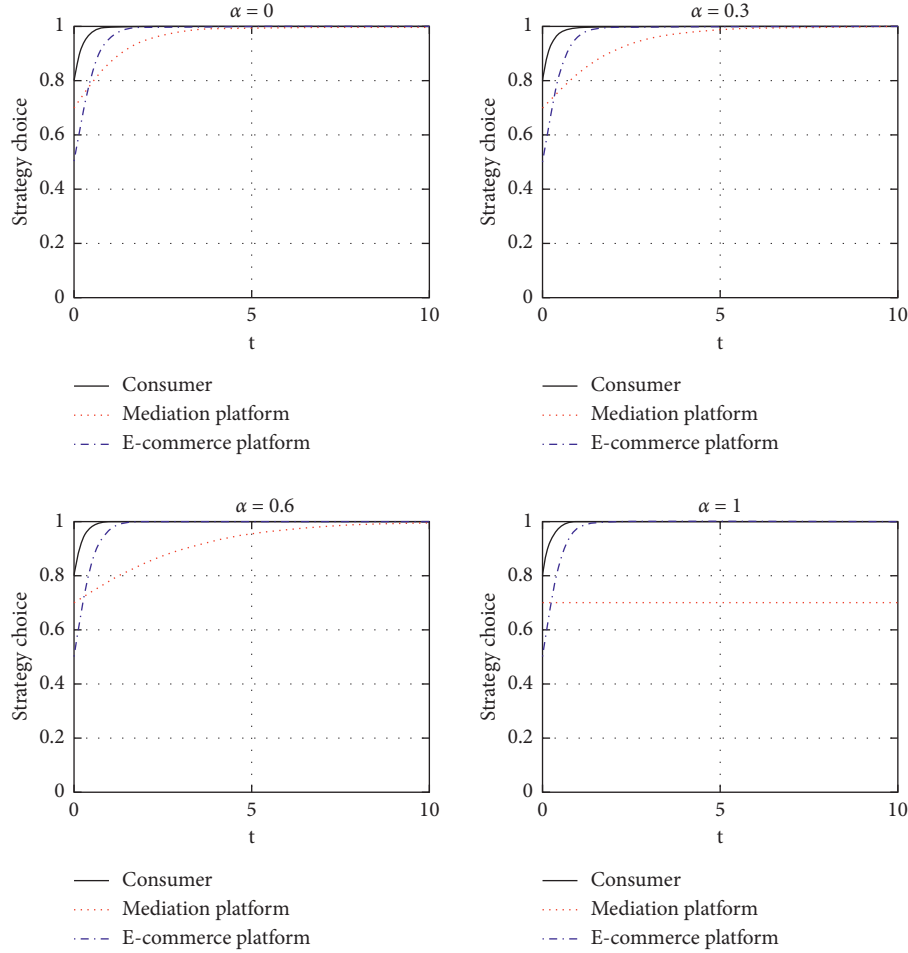
FIGURE 5: Influence of the probability of the e-commerce platform being enrolled in the mediation platform.

consumer and e-commerce platform, at least should meet $D_1 \geq -D_2 + T_1 - T_2$.

4. Numerical Analysis

In this section, numerical values are brought in for simulation to analyze the effect of the relevant parameters on the process.

Numerical values are given in conjunction with the actual situation, and simulation is performed using MATLAB 2020b. The 'sky-eye search' data shows that there are over 3.78 million e-commerce related enterprises in China, but most e-commerce enterprises are relatively small, and the probability of the e-commerce platform is in the mediation platform is low, so assume that $\alpha = 0.3$. When consumers make a distortion complaint, The measures taken by the mediation platform are only to dismiss the complaint and ban the relevant account, so the punishment for consumers' complaints is small, so let $S = 0.5$. According to the actual situation let $p = 0.8$, $q = 0.7$, $g = 0.5$.

4.1. Influence of the Probability of the E-Commerce Platform Being Enrolled in the Mediation Platform. The probability of the e-commerce platform being enrolled in the mediation

platform are dissatisfied, so that $\alpha = \{0, 0.3, 0.6, 1\}$, then the game subject strategy evolution process and the impact results, as shown in Figure 5.

As can be seen from Figure 5, the probability of the e-commerce platform being enrolled in the mediation platform mainly has a greater impact on the mediation platform and a smaller impact on the consumer and e-commerce platform. As the probability of the e-commerce platform entering the mediation platform increases, the mediation platform will take positive measures to deal with the settled e-commerce platform. Due to the limited resources and energy of the mediation platform, the mediation platform will call more resources to serve the settled e-commerce platform. Therefore, the probability of positively dealing with complaints against nonsettled platforms will be reduced.

4.2. Influence of the Probability of Consumer Being Dissatisfied with the Outcome When the E-Commerce Platform Is Handled Negatively. The probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively is dissatisfied, so that $\beta = \{0, 0.2, 0.6, 1\}$ and, then the game subject strategy evolution process and the impact results, as shown in Figure 6.
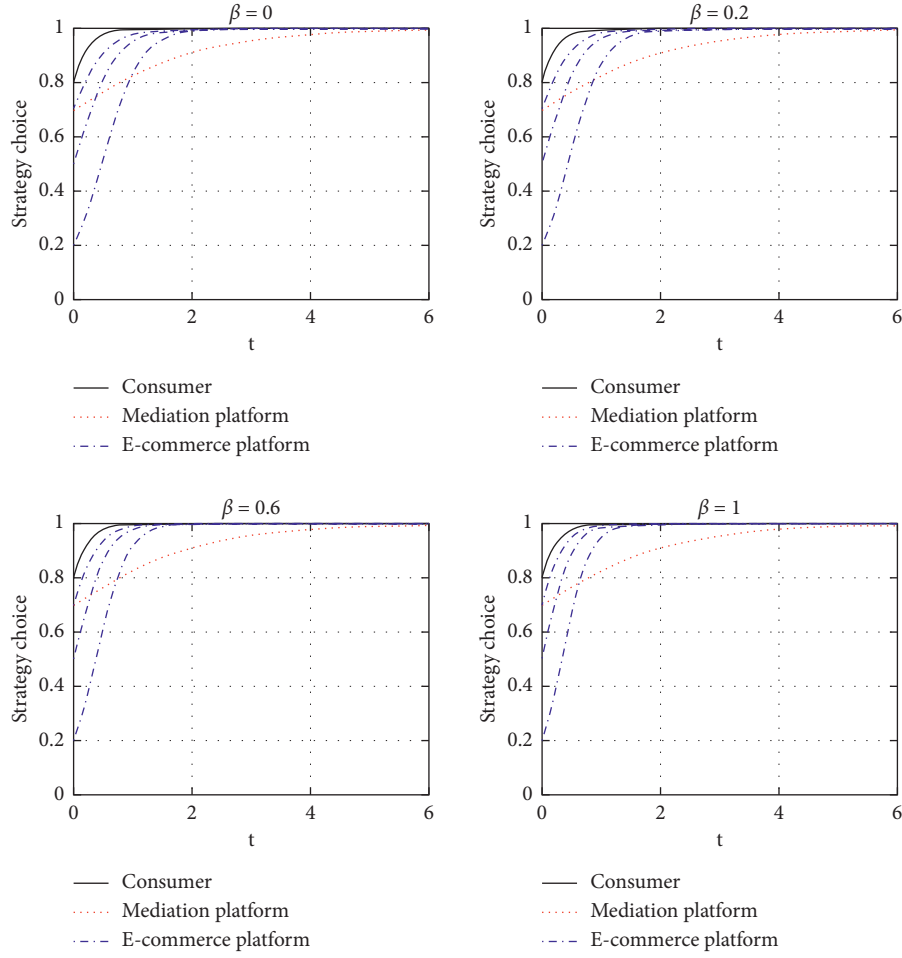
FIGURE 6: Influence of t the probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively.

As can be seen from Figure 6, the probability of consumers being dissatisfied with the outcome when the e-commerce platform is handled negatively has a greater impact on the strategy choice of the e-commerce platform. With the increase of the probability that consumers are dissatisfied with the processing results when the e-commerce platform handles negatively, the probability that the e-commerce platform chooses to handle positively will increase. This is because consumers' dissatisfaction with the complaint handling results will reduce consumers' trust in the e-commerce platform and affect the reputation of the e-commerce platform, thus forcing the e-commerce platform to positively handle consumer complaints and restore the reputation of the e-commerce platform. Improving consumers' awareness of rights protection can effectively inhibit the negative handling of consumer complaints by the e-commerce platform.

4.3. Influence of Factors Leading to the Loss of E-Commerce Platform Reputation on the Choice of E-Commerce Platform Strategy. Loss of reputation of the e-commerce platform due to negative reports on the mediation platform and consumer's dissatisfaction with the result of processing are changed, so that $N_2 = \{0, 1, 1.5, 2, 2.5, 3\}$ and $X_2 = \{0, 0.5, 0.9, 1.5, 3, 8\}$, then the process of e-commerce platform strategy evolution and the impact results, as shown in Figure 7.

As can be seen from Figure 7, the evolution rate of the e-commerce platform towards positively handling consumer complaints increases with the increase of reputation loss of the e-commerce platform caused by negative reports of mediation platforms. Consumers' dissatisfaction with the handling results leads to increased reputation loss of the e-commerce platform, which can promote the evolution of the e-commerce platform to positively handle consumer complaints. It can be seen that the greater the impact on the reputation loss of the e-commerce platform, the more the e-commerce platform tends to choose to positively deal with consumer complaints. This is because the negative reports of the mediation platform, the low ranking of the list and other behaviors, and consumers' dissatisfaction with the processing results will hurt the reputation of the e-commerce platform. To recover customers lost due to bad reputation, the e-commerce platform will positively and quickly deal with consumer complaints, recover lost customers, and re-establish a good platform image. Therefore, improving the
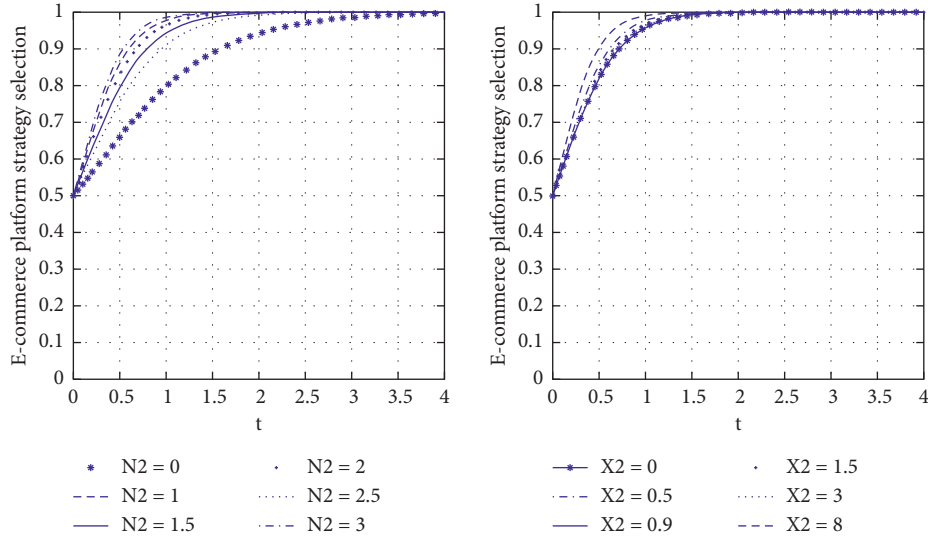
FIGURE 7: Influence of factors leading to the loss of e-commerce platform reputation on the choice of e-commerce platform strategy.

influence of consumers and mediation platforms on the e-commerce platform can improve the enthusiasm of the e-commerce platform to deal with consumer complaints, to build a better relationship between consumers and the e-commerce platform.

4.4. Influence of Strategy Choice of Game Subjects. The probability of each game subject's strategy choice is changed, then the process of strategy evolution and influence results of the consumer, mediation platform, and e-commerce platform, as shown in Figure 8.

As can be seen from Figure 8, changing the probability of consumers' real complaint, the probability of mediation platform's positive handling and the probability of e-commerce platform's positive handling yields unstable equilibriums $(1, q, 1)$ and $(0, 0, g)$, and the system exists a combination of evolutionarily stable strategies (consumer's distorted complaint, mediation platform's negative handling, e-commerce platform's negative handling), (consumer's real complaint, mediation platform's positive handling, e-commerce platform's positive handling), (consumer's real complaint, mediation platform's negative handling, e-commerce platform's positive handling). Therefore, consumers themselves should improve their awareness of safeguarding their rights. If they are not satisfied with consumption, they should positively complain. The mediation platform itself should strengthen the supervision and review of consumers and the e-commerce platform to promote the settlement of the e-commerce platform. Improve the credibility and influence of the mediation platform, to increase the trust of the e-commerce platform and consumers in the mediation platform, so that the mediation platform can better urge the e-commerce platform to deal with consumer complaints. The e-commerce platform should improve the awareness of after-sales service and consumer satisfaction, to improve the reputation of the platform and attract more consumers.
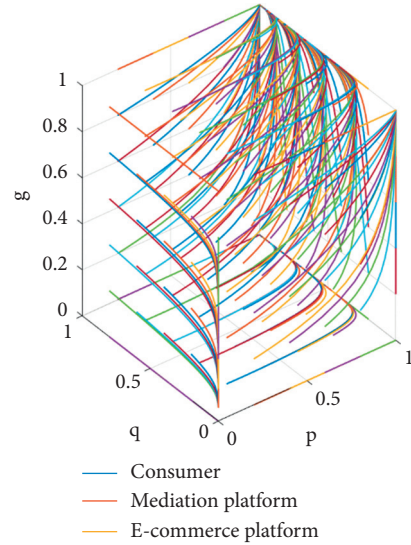

FIGURE 8: Influence of strategy choice of game subjects.

5. Conclusion

The e-commerce dispute mediation platform is introduced, and the evolutionary game model with the consumer, mediation platform, and e-commerce platform as the main subjects is constructed, while the probability of the e-commerce platform being enrolled in the mediation platform and the probability of consumer being dissatisfied with the outcome when the e-commerce platform is handled negatively are introduced to be more realistic. The stability analysis of each game subject shows the influencing factors of each subject's strategy choice, and the influence of the main influencing factors on the strategy choice of the game subject is discussed through numerical simulation and emulation. The main conclusions of the study are as follows:

(i) The rate of consumer real complaint can be increased when the probability of the mediation platform and

e-commerce platform positively handling complaint increases, the penalty for consumer distortion complaint is higher, the real complaint cost of the consumer is lower, and the distorted complaint cost of the consumer is higher. (ii) The probability of the mediation platform positively handling consumer complaints increases with the increase in the probability of consumers' real complaints and the increase in the impact of the mediation platform's handling strategies on their reputation. (iii) With the increase in the probability of consumer's true complaint and the mediation platform's positive handling, the increase in the probability of the e-commerce platform being enrolled in the mediation platform, the lower positive handling cost of e-commerce platform, the increase in the reputational impact of consumers on the e-commerce platform, the increase in the loss of reputation of the mediation platform due to negative handling of a real complaint by the mediation platform, and the increase in the mediation platform on the impact of e-commerce platform reputation, the e-commerce platform tends to choose the positive handling strategy.

For the e-commerce platform to positively handle consumer complaints, and thus make the entire e-commerce industry sustainable, the behavior of all three parties - the consumer, the mediation platform, and the e-commerce platform - must be positive and honest. (i) Consumers should have a sense of integrity and not make exaggerated or even false complaints; consumers themselves should also raise their awareness of their rights, legally defend their rights, and positively pursue secondary complaints if they are not satisfied with the results of the complaint mediation. (ii) The e-commerce platform should improve the awareness of after-sales service and positively deal with consumer complaints. The e-commerce platform should also be positively stationed in the mediation platforms and urge themselves to positively deal with consumer complaints through a series of services of the mediation platforms. (iii) Improving the credibility and influence of the mediation platforms is an important part of motivating the e-commerce platform to positively handle consumer complaints. Therefore, to improve the credibility and influence of the mediation platforms, the mediation platforms themselves should increase the supervision and review of consumers and the e-commerce platform, and positively promote the "exposure desk", "case study", "e-commerce rating", "list" and other operations. The mediation platforms can positively promote the consumer rating system, increase the service and publicity for the resident merchants, promote the entry of the e-commerce platform, urge the e-commerce platform to deal with consumer complaints, increase the docking and cooperation with social media, and constantly optimize the system to simplify the procedures for consumer complaints, etc. At present, the mediation platforms' punishment for consumers who complain about distortion is relatively small and is simply a blocking process. The mediation platforms need to improve supervision and punishment efforts and impose a certain degree of punishment

on consumers who complain about distortion and on the e-commerce platform that deals with it negatively.

This paper addresses the evolutionary game among the consumer, mediation platform, and e-commerce platform. In fact, for the e-commerce platform with merchants on board, they also need to interface with merchants, and some complaints need to be handled by merchants; in reality, consumers who are not satisfied with the processing results may make secondary complaints; e-commerce ratings need to consider feedback time, consumer ratings and other factors, but they are not considered in this study. Subsequent studies can be conducted around this.

Appendix

Proof of Proposition 1. Let $R(q,g) = -J + Jq + S - J\beta + g(J - Jq + J\beta) + A - C_1 + C_2$, $\partial R(q,g)/\partial q = (1-g)J\rangle 0$, $\partial R(q,g)/\partial g = J(1-q) + J\beta\rangle 0$, $R(q,g)$ is positively correlated with q, g. Under $0 \leq q_0 \leq 1$ and $0 \leq g_0 \leq 1$, when $q\rangle q_0, g\rangle g_0$, $R(q,g)\rangle 0$, $F(p)|_{p=1} = 0$, $F\prime(p)|_{p=1}\langle 0$, at $p = 1$ stable; when $q\langle q_0, g\langle g_0, R(q,g)\langle 0, F(p)|_{p=0} = 0$, $F\prime(p)|_{p=0}\langle 0$, at $p = 0$ stable; when $q = q_0$, $g = g_0$, $R(q,g)\langle 0, F(p) = 0$, $F'(p) = 0$, Stability is uncertain. End of proof. $\square$

Proof of Corollary 1. Under $i\langle 1/e$, $\partial V_{p1}/\partial S = \partial V_{p1}/\partial C_2 = 1 + \ln i/J\rangle 0$, $\partial V_{p1}/\partial C_1 = -1 + \ln i/J\langle 0$. When $S\uparrow$, $C_1\downarrow$ or $C_2\uparrow$, $V_{p1}\uparrow$. End of proof. $\square$

Proof of Corollary 2. From Proposition 1, $q_0\uparrow$, $q\langle q_0$, the stable strategy for the consumer is distortion complain. $\partial q_0/\partial J = (S + A - C_1 + C_2)/[(1-g)J^2]$, $V_{p1}/\partial \beta = (S + A - C_1 + C_2)/(J\beta + J\beta^2)$. When $S + A - C_1 + C_2\langle 0$, $\partial q_0/\partial J\langle 0$, $\partial V_{p1}/\partial \beta\rangle 0$. When $S + A - C_1 + C_2\rangle 0$, $\partial q_0/\partial J\rangle 0$, $\partial V_{p1}/\partial \beta\langle 0$. When $S + A - C_1 + C_2 = 0$, $\partial q_0/\partial J/ = \partial V_{p1}/\partial \beta = 0$. If change J does not affect q_0. If change β does not affect V_{p1}. $\square$

Proof of Proposition 2. When $\alpha = 1$, $F(q) = 0$, $F'(q) = 0$, mediation platform selects complaint handling strategy uncertainty. Let $Q(p) = p(D_1 + D_2) - T_1 + T_2$, $\partial Q(p)/\partial p = D_1 D_1 + D_2\rangle 0$, $p\uparrow$, $Q(p)\uparrow$. Under $p_1 < 0$, $Q(p) > 0$ is constant, $F(q)|_{q=1} = 0$, $F\prime(q)|_{q=1} < 0$, mediation platform stabilizes the choice of positive handling strategy. When $p_1 > 1$, $Q(p) < 0$ is constant, $F(q)|_{q=0} = 0$, $F\prime(q)|_{q=0} < 0$, mediation platform stabilizes the selection of negative handling strategy. Same reason, under $0 \leq p_1 \leq 1$, when $p > p_1$, $Q(p) > 0$, $F(q)|_{q=1} = 0$, $F\prime(q)|_{q=1} < 0$, the mediation platform stabilizes the choice of positive handling strategy; when $p < p_1$, $Q(p) < 0$, $F(q)|_{q=0} = 0$, $F\prime(q)|_{q=0} < 0$, the mediation platform stabilizes the selection of negative handling strategy; when $p = p_1$, $Q(p) = 0$, $F(q) = 0$, $F\prime(q) = 0$, the mediation platform chooses an uncertain complaint handling strategy. End of proof. $\square$

Proof of Corollary 3. $\partial V_{p1}/\partial D_1 = -(2(T_1 - T_2)^2/(D_1 + D_2)^3) < 0$, $\partial V_{p1}/\partial D_2 = -(2(T_1 - T_2)^2/(D_1 + D_2)^3) < 0$. When $D_1\uparrow$ or $D_2\uparrow$, $V_{p1}\uparrow$. $\square$

Proof of Corollary 4. When $0 \leq (T_1 - T_2)/(D_1 + D_2) \leq 1$, $\partial p_1/\partial T_1 = 1/(D_1 + D_2) \rangle 0$, $\partial p_1/\partial T_2 = -1/(D_1 + D_2) \langle 0$. When $T_1 \downarrow$ or $T_2 \uparrow$, $p \rangle p_1$, mediation platform stabilizes the choice of positive handling strategy. End of proof. □

Proof of Proposition 3. Let $W(p,q) = pa + (1-p)(1-q)b$, $\partial W(p,q)/\partial p = a + (1-q)b$, $\partial W(p,q)/\partial q = (1-p)b$. Because $a + (1-q)b > 0$, $(1-p) > 0$, $(1-q) > 0$, $(1-\alpha) > 0$, $Q_1 > Q_2$, therefore $\partial W(p,q)/\partial p > 0$, $\partial W(p,q)/\partial q > 0$. That is, $W(p,q)$ is positively correlated with p and q. Under $0 \leq a/[a + (1-q)b] \leq 1$ and $0 \leq pa/[(1-p)b] \leq 1$, when $p > p_2$ and $q > q_2$, $W(p,q) > 0$, $F(g)|_{g=1} = 0$, $F\prime(g)|_{g=1} < 0$, stable choice of positive handling strategy for e-commerce platform; when $p < p_2$ and $q < q_2$, $W(p,q) < 0$, $F(g)|_{g=0} = 0$, $F\prime(g)|_{g=0} < 0$, stable choice of negative handling strategy for e-commerce platform; when $p = p_2$, and $q = q_2$, $W(p,q) = 0$, $F(g) = 0$, $F'(g) = 0$, uncertainty of complaint handling strategy for e-commerce platform. End of proof. □

Proof of Corollary 5. It follows from Proposition 3 that $p_2 \downarrow$, $p > p_2$ increased probability of the e-commerce platform choosing aggressive handling strategy. Under $0 \leq a/a + (1-q)b \leq 1$, because $0 \leq q \leq 1$, $Q_1 > Q_2$, it follows from Corollary 5 that $-L_1 + L_2 + N_1 + N_2 + \beta X_1 + \beta X_2 > 0$, therefore $(\partial p_2/\partial \alpha) = -(1-q)(Q_1 - Q_2)[N_1 + N_2 + \beta(X_1 + X_2)]/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta\ X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \leq 0$ $\partial p_2/\partial L_1 = (1-q)(1-\alpha)^2 (Q_1 - Q_2)/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \geq 0$, $\partial p_2/\partial L_2 = -(1-q)(1-\alpha)^2 (Q_1 - Q_2)/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \leq 0$, $/\partial Q_1 = (1-q)(1-\alpha)[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta(X_1 + X_2)]/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \geq 0$, $\partial p_2/\partial Q_2 = -(1-q)(1-\alpha)[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta(X_1 + X_2)]/$

$$\left[\begin{array}{c}(1-\alpha)(L_2 - L_1) + N_1 + N_2 \\ +\beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)\end{array}\right]^2 \leq 0, \partial p_2/\partial X_1 =$$

$\partial p_2/\partial X_2 = -(1-q)(1-\alpha)(Q_1 - Q_2)\beta/$

$$\left[\begin{array}{c}(1-\alpha)(L_2 - L_1) + N_1 \\ +N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)\end{array}\right]^2 \leq 0, \partial p_2/$$

$\partial N_1 = \partial p_2/\partial N_2 = -(1-q)(1-\alpha)(Q_1 - Q_2)/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + \beta X_1 + \beta X_2 + (1-q)(1-\alpha)(Q_1 - Q_2)]^2 \leq 0$, $\partial p_2/\partial \beta = -(1-q)(1-\alpha)(Q_1 - Q_2)(X_1 + X_2)/[(1-\alpha)(L_2 - L_1) + N_1 + N_2 + (-1+q)(-1+\alpha)(Q_1 - Q_2) + \beta(X_1 + X_2)]^2 \leq 0$. $L_1 \downarrow$, $q \downarrow$, $Q_1 \downarrow$, $\alpha \uparrow$, $L_2 \uparrow$, $N_1 \uparrow$, $N_2 \uparrow$, $Q_2 \uparrow$, $X_1 \uparrow$, $X_2 \uparrow$, $\beta \uparrow$, then $p_2 \downarrow$. End of proof. □

Data Availability

The data used to support the findings of this paper are included within the article (Numerical Analysis section).

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

[1] M. Frasquet, M. Ieva, and C. Ziliani, "Understanding complaint channel usage in multichannel retailing," *Journal of Retailing and Consumer Services*, vol. 47, pp. 94–103, 2019.

[2] D. Raval, "Whose voice do we hear in the marketplace? Evidence from consumer complaining behavior," *Marketing Science*, vol. 39, no. 1, pp. 168–187, 2020.

[3] D. Istanbulluoglu, S. Leek, and I. T. Szmigin, "Beyond exit and voice: developing an integrated taxonomy of consumer complaining behaviour," *European Journal of Marketing*, vol. 51, no. 5/6, pp. 1109–1128, 2017.

[4] S. D. Arora and A. Chakraborty, "Intellectual structure of consumer complaining behavior (CCB) research: a bibliometric analysis," *Journal of Business Research*, vol. 122, pp. 60–74, 2021.

[5] B. W. Ateke and H. Harcourt, "Perceived satisfaction with organizational response to complaint and repeat purchase intention," *International Journal of Economics and Business Management*, vol. 3, no. 6, pp. 11–24, 2017.

[6] H. O. Awa, N. K. Ikwor, and D. G. Ademe, "Customer satisfaction with complaint responses under the moderation of involvement," *Cogent Business & Management*, vol. 8, no. 1, Article ID 1905217, 2021.

[7] Z. Li, "From power to punishment: consumer empowerment and online complaining behaviors," *Internet Research*, vol. 29, no. 6, pp. 1324–1343, 2019.

[8] J. L. Stevens, B. I. Spaid, M. Breazeale, and C. L. Esmark Jones, "Timeliness, transparency, and trust: a framework for managing online customer complaints," *Business Horizons*, vol. 61, no. 3, pp. 375–384, 2018.

[9] H. Crijns, V. Cauberghe, L. Hudders, and A.-S. Claeys, "How to deal with online consumer comments during a crisis? The impact of personalized organizational responses on organizational reputation," *Computers in Human Behavior*, vol. 75, pp. 619–631, 2017.

[10] M. Johnen and O. Schnittka, "When pushing back is good: the effectiveness of brand responses to social media complaints," *Journal of the Academy of Marketing Science*, vol. 47, no. 5, pp. 858–878, 2019.

[11] H. He and L. Zhu, "Online shopping green product quality supervision strategy with consumer feedback and collusion behavior," *PloS one*, vol. 15, no. 3, Article ID e0229471, 2020.

[12] Y. Hwang and A. S. Mattila, "The impact of customer compassion on face-to-face and online complaints," *Journal of Hospitality Marketing & Management*, vol. 29, no. 7, pp. 848–868, 2020.

[13] R. Cai and C. G.-Q. Chi, "The impacts of complaint efforts on customer satisfaction and loyalty," *Service Industries Journal*, vol. 38, no. 15-16, pp. 1095–1115, 2018.

[14] S. A. Einwiller and S. Steilen, "Handling complaints on social network sites - an analysis of complaints and complaint

responses on Facebook and Twitter pages of large US companies," *Public Relations Review*, vol. 41, no. 2, pp. 195–204, 2015.

[15] D. Istanbulluoglu, "Complaint handling on social media: the impact of multiple response times on consumer satisfaction," *Computers in Human Behavior*, vol. 74, pp. 72–82, 2017.

[16] J. G. Lemos, M. V. Garcia, R. de Oliveira Mello, and M. V. Copetti, "Consumers complaints about moldy foods in a Brazilian website," *Food Control*, vol. 92, pp. 380–385, 2018.

[17] I. Sahin, M. Gulmez, and O. Kitapci, "E-complaint tracking and online problem-solving strategies in hospitality management: plumbing the depths of reviews and responses on TripAdvisor," *Journal of Hospitality and Tourism Technology*, vol. 8, 2017.

[18] B. Koh, I.-H. Hann, and S. Raghunathan, "Digitization of music: consumer adoption amidst piracy, unbundling, and rebundling," *MIS Quarterly*, vol. 43, no. 1, pp. 23–45, 2019.

[19] M.-J. Miquel-Romero, M. Frasquet, and A. Molla-Descals, "The role of the store in managing postpurchase complaints for omnichannel shoppers," *Journal of Business Research*, vol. 109, pp. 288–296, 2020.

[20] D. Yuan, Z. Lin, R. Filieri, R. Liu, and M. Zheng, "Managing the product-harm crisis in the digital era: the role of consumer online brand community engagement," *Journal of Business Research*, vol. 115, pp. 38–47, 2020.

[21] P. Gunarathne, H. Rui, and A. Seidmann, "Whose and what social media complaints have happier resolutions? Evidence from Twitter," *Journal of Management Information Systems*, vol. 34, no. 2, pp. 314–340, 2017.

[22] A. Javornik, R. Filieri, and R. Gumann, "Don't forget that others are watching, too!" the effect of conversational human voice and reply length on observers' perceptions of complaint handling in social media," *Journal of Interactive Marketing*, vol. 50, pp. 100–119, 2020.

[23] F. Zhan, W. Luo, and J. Luo, "Exhibition attachment: effects on customer satisfaction, complaints and loyalty," *Asia Pacific Journal of Tourism Research*, vol. 25, no. 6, pp. 678–691, 2020.

[24] R. M. Kowalski, "Complaints and complaining: functions, antecedents, and consequences," *Psychological Bulletin*, vol. 119, no. 2, pp. 179–196, 1996.

[25] I. P. Riquelme, S. Román, P. J. Cuestas, and D. Iacobucci, "The dark side of good reputation and loyalty in online retailing: when trust leads to retaliation through price unfairness," *Journal of Interactive Marketing*, vol. 47, pp. 35–52, 2019.

[26] X. Y. Mei, I. K. Bagaas, and E. K. L. Relling, "Customer complaint behaviour (CCB) in the retail sector: why do customers voice their complaints on Facebook?" *International Review of Retail Distribution & Consumer Research*, vol. 29, no. 1, pp. 63–78, 2019.

[27] J. Boote, "Towards a comprehensive taxonomy and model of consumer complaining behaviour," *Journal of Consumer Satisfaction, Dissatisfaction and Complaining Behavior*, vol. 11, pp. 140–151, 1998.

[28] C. Brennan, T. Sourdin, J. Williams, N. Burstyner, and C. Gill, "Consumer vulnerability and complaint handling: challenges, opportunities and dispute system design," *International Journal of Consumer Studies*, vol. 41, no. 6, pp. 638–646, 2017.

[29] L. Lu, D. Gursoy, C. G.-Q. Chi, and G. Xiao, "Developing a consumer complaining and recovery effort scale," *Journal of Hospitality & Tourism Research*, vol. 42, no. 5, pp. 686–715, 2018.

[30] K. Bastani, H. Namavari, and J. Shaffer, "Latent Dirichlet allocation (LDA) for topic modeling of the CFPB consumer complaints," *Expert Systems with Applications*, vol. 127, pp. 256–271, 2019.

[31] pp. 28–31, !!! INVALID CITATION !!!.

[32] Z. Yu, M. Tianshan, S. A. Rehman, A. Sharif, and L. Janjua, "Evolutionary Game of End-Of-Life Vehicle Recycling Groups under Government Regulation," *Clean Technologies And Environmental Policy*, vol. 28, pp. 1–12, 2020.

[33] W. Chen and Z.-H. Hu, "Using evolutionary game theory to study governments and manufacturers' behavioral strategies under various carbon taxes and subsidies," *Journal of Cleaner Production*, vol. 201, pp. 123–141, 2018.

[34] X. Xing, Z. Hu, and W. Luo, "Using evolutionary game theory to study governments and logistics companies' strategies for avoiding broken cold chains," *Annals of Operations Research*, vol. 2, 2020.

[35] X. Zhao, L. Ren, Y. Zhang, and G. Wan, "Evolutionary game analysis on the behavior strategies of power producers in renewable portfolio standard," *Energy*, vol. 162, pp. 505–516, 2018.

[36] X. Liu, W. Wang, D. Niyato, N. Zhao, and P. Wang, "Evolutionary game for mining pool selection in blockchain networks," *IEEE Wireless Communications Letters*, vol. 7, no. 5, pp. 760–763, 2018.

[37] Z. Zhang, Y. Xue, J. Li, L. Gong, and L. Wang, "Supply chain logistics information collaboration strategy based on evolutionary game theory," *IEEE Access*, vol. 8, Article ID 46102, 2020.

[38] Y. Zhang, W. Chen, and Y. Mi, "Third-party remanufacturing mode selection for competitive closed-loop supply chain based on evolutionary game theory," *Journal of Cleaner Production*, vol. 263, Article ID 121305, 2020.

[39] H. Sun, Y. Wan, L. Zhang, and Z. Zhou, "Evolutionary game of the green investment in a two-echelon supply chain under a government subsidy mechanism," *Journal of Cleaner Production*, vol. 235, pp. 1315–1326, 2019.

[40] F. Feng, C. Liu, and J. Zhang, "China's railway transportation safety regulation system based on evolutionary game theory and system dynamics," *Risk Analysis*, vol. 4, 2020.

[41] L. Ma and L. Zhang, "Evolutionary game analysis of construction waste recycling management in China," *Resources, Conservation and Recycling*, vol. 161, Article ID 104863, 2020.

[42] Q. Liu, X. Li, and M. Hassall, "Evolutionary game analysis and stability control scenarios of coal mine safety inspection system in China based on system dynamics," *Safety Science*, vol. 80, pp. 13–22, 2015.

[43] K. Kang, Y. Zhao, J. Zhang, and C. Qiang, "Evolutionary game theoretic analysis on low-carbon strategy for supply chain enterprises," *Journal of Cleaner Production*, vol. 230, pp. 981–994, 2019.

[44] J. Sheng, W. Zhou, and B. Zhu, "The coordination of stakeholder interests in environmental regulation: lessons from China's environmental regulation policies from the perspective of the evolutionary game theory," *Journal of Cleaner Production*, vol. 249, Article ID 119385, 2020.