Green Product Quality Supervision Strategy in Online Shopping With Consumer Evaluation and Complaint

Hui He¹, Siyi Zhang¹ and Lilong Zhu¹,²*

¹School of Business, Shandong Normal University, Ji’nan, China, ²Quality Research Center, Shandong Normal University, Ji’nan, China

Green consumption is an important foundation for achieving stable and long-term economic development goals. With the rapid development of e-commerce and people’s widespread attention to sustainability, more and more consumers purchase green products online. Therefore, we consider consumer feedback mechanisms including evaluation and complaint and construct an evolutionary game model of green product quality supervision with the participation of governmental supervision department, third-party e-commerce platform, online seller and consumer, which analyzes the four parties’ evolutionary stable strategies. To verify the theoretical results, we conduct a numerical simulation by Matlab 2020b. Moreover, we study the conditions that make evolutionary stable strategy combination exist based on Lyapunov’s First Method. And we find that when consumer chooses complaint, (0, 0, 1) is likely to become an only evolutionary stable strategy combination. At this time, the online seller chooses to provide high-quality green product, third-party e-commerce platform chooses not to strengthen inspection, and governmental supervision department chooses to strictly supervise. Conversely, when the consumer chooses no complaint, (1, 0, 0) and (0, 0, 1) may become an evolutionary stable strategy combination. At this time, the online seller cannot be stable in providing high-quality green product. What’s more, governmental supervision department increases the penalty, which can incentivize a third-party e-commerce platform to strengthen inspection. Third-party e-commerce platform increases the reward and can promote online seller to provide high-quality green product. On the one hand, this paper enriches the theoretical basis of online shopping green product quality supervision. On the other hand, compared with existing literature, it extends the main body of the evolutionary game to four paries and broadens the application scope of the game model. In addition, it has put forward feasible suggestions for the government supervision department to strengthen the quality supervision, and provided decision-making support for the third-party e-commerce platform to assume the responsibility of quality inspection.

Keywords: green product quality supervision, online shopping, consumer evaluation, consumer complaint, evolutionary game
INTRODUCTION

The growth of e-commerce is transforming shopping consumption from offline to online. According to Global E-commerce Data Report, online retail transactions of China, the United States, the United Kingdom, and Japan were 1,309.5 billion dollars, 520 billion dollars, 291 billion dollars, and 179 billion dollars in 2019, with growth rates of 25.5, 15.8, 11.1, and 19.1%, respectively. The prosperous development of online shopping provides a broad platform for green products. Green product refers to what meets specific environmental protection requirements during the entire process of production, processing, transportation, consumption, and recycling, and has the lowest harm to the ecological environment, the highest resource utilization, and the least energy consumption. Online shopping green product not only brings great convenience but also satisfies consumers’ demands for environmental protection. Consumers are paying more and more attention to green product quality. However, there are some serious problems, such as the lack of government supervision, insufficient inspection of third-party e-commerce platform, irregularities in green product certification standards, illegal sales of online seller, and invalid complaint of consumers.

In some countries, such as China, the United States, the United Kingdom, and Japan, many corresponding measures have been taken. China began to implement the e-commerce law in 2019, which clarified the issues of counterfeit sales and consumer rights protection. The United States has established a cross-departmental e-commerce management agency and government e-commerce working group, implemented strict unreasonable return system, and also built the Better Business Bureau for consumer complaint and rights protection. The United Kingdom has established a special office which is responsible for monitoring whether companies have reached the relevant standards of product and service, and implemented some laws and regulations, such as the E-commerce Regulations and the United Kingdom Consumer Protection Act, which have provided a basis for the e-commerce supervision. Japanese e-commerce started late, but its development speed is rapid. The Japanese government has formulated a series of laws and regulations, such as Electronic Consumer Contract Law, Resolution Framework for Consumer Disputes in Electronic Commerce, which intensify the supervision of e-commerce transactions. Despite many countries having made great efforts, online shopping green product quality problems have not been solved. There is a need to further study how to achieve effective supervision.

More and more practice show that consumer feedback is becoming increasingly important in online shopping, and product quality problems need to be solved by multiple parties (Li et al., 2015). Therefore, this paper considers a consumer feedback mechanism including evaluation and complaint and constructs an evolutionary game model with the participation of governmental supervision department, third-party e-commerce platform, online seller, and consumer. We analyze each party’s evolutionary stable strategy and factors’ influence on four parties’ strategic choices. Based on the Lyapunov’s First Method (Liu et al., 2015), we study the conditions that make evolutionary stable strategy combination exist, and verify our theoretical analysis results with numerical simulation by Matlab 2020b. This paper aims to solve the following questions: How does consumer evaluation and complaint influence each party’s strategic choice? How does a third-party e-commerce platform design reasonable reward and penalty to incentivize the online seller to provide high-quality green products? How does a governmental supervision department make effective supervision strategies to improve online shopping green product quality?

The rest of our paper is organized as follows. In Literature Review, we review relevant research on online shopping green product quality. We make assumptions and construct an evolutionary game model in Model Assumptions and Construction. In The Stability Analysis of Strategic Choices, each party’s strategy stability is analyzed. In Stability Analysis of Strategy Combination, we analyze the strategy combination's stability based on the Lyapunov’s First Method. In Numerical Simulation Analysis, we conduct numerical simulation by Matlab 2020b, which analyzes factors’ influence on the evolutionary stable strategy combination. At last, suggestions and advice are provided in Summary. Throughout the paper, from the abstract, introduction, literature review, method, to the final conclusion, we refer to some excellent references to improve the study (Abbas et al., 2019; Aman et al., 2019; Mubeen et al., 2020; Abbasi et al., 2021).

LITERATURE REVIEW

Online Shopping Product Quality

As we know, the spread of COVID-19 creates disruption, uncertainty, complexity, and ambiguity in all walks of life (Azizi et al., 2021). People’s demand for online shopping has greatly increased. However, product quality is also worrying. The serious information asymmetry between consumer and online seller is the root cause of online shopping product quality problems. Information about product quality will affect consumers’ purchase intention (Zhou et al., 2018), and the consumer usually makes assessment through the information about product quality provided by a third-party e-commerce platform and online seller (Mavlanova et al., 2012). For the online seller, disclosing the transaction data timely makes it easier to attract customers (Subramanian and Rao, 2016). Correct information is indispensable to dispel uncertainty (Abbas et al., 2021). Information sharing helps companies become more dynamic, innovative, and competitive (Abbas et al., 2019). Competitive online sellers tend to disclose as much product information as possible (Tao et al., 2018). Low-quality online sellers, however, may use the information transmission mechanism to pretend to be a high-quality seller and sell low-quality product (Fouliras, 2013), which leads to increasingly serious online shopping product quality problems. As consumers’ awareness of rights protection increases, the return rate has gradually increased, resulting in the increasing cost of stakeholders’ return management (Shang et al., 2017). Therefore, a third e-commerce platform has the motivation to strengthen
inspection of online seller’s qualification and provide the consumer with reliable information (Loureiro et al., 2012). But actually, in order to pursue higher profits, the collusion between third-party e-commerce platform and online seller usually occurs (Park and Ju, 2016).

Online shopping product problems are very common in many countries, which have aroused many researchers’ attention. They have proposed various mechanisms such as supervision mechanism (Li et al., 2018), revenue sharing mechanism (Zhang et al., 2019), return management system (Griffis et al., 2012; Seung, 2014), supply chain management system (Kaynak and Hartley, 2008; Zhu, 2020), reward and penalty system (He and Zhu, 2020). Scholars usually conduct research from a single party perspective. But in fact, the product quality problems involve multiple parties. Therefore, this paper constructs an evolutionary game model involving four parties.

Green Product
In the late 1980s and early 1990s, the term of green was created in the marketing field (Wang et al., 2020). With the progress of society, balancing the relationship between economic development and environmental protection has become a hot topic (Bai et al., 2020). Correspondingly, green and sustainability are considered to be particularly common in production, consumption, and other fields. From the perspective of the consumer, the consumer pays more attention to sustainability and environmental protection and prefers to buy green products (Hong and Guo, 2019). However, green product quality still falls short of consumers’ expectations. From the perspective of the seller, compared with non-green product, green product does have moral advantages while it has disadvantages in price (Dixon and Mikolon., 2020). The R&D, production, sales, recycling, and other links of green product all require higher costs, which may discourage producer and seller from improving product quality. From the perspective of the government, government usually provides higher subsidies and lower taxes to producer and seller (Sana, 2020). And the continuous improvement of green standards also can improve a green product’s environmental benefits (Gao et al., 2020). Strict enforcement of regulations by government in practice is an effective incentive measure. What needs to be paid attention to is that government should implement regulations carefully, because overly strict regulations may cause producer and seller to be reluctant to innovate, and gain higher profits at the cost of reducing overall environmental performance (Maryam and Hossein, 2018). Market competition can stimulate producer and seller to make choices that meet public requirements (Guo et al., 2019). It can be seen that most of the existing researches study product quality supervision, but are less involved in green product quality supervision, so this paper analyzes how to supervise green product quality in online shopping.

Consumer Evaluation
Positive evaluation is usually related to the product itself (Ahmad and Laroche, 2016), and negative evaluation has a great impact on management and service quality (Chevalier et al., 2018). Effective social evaluation can reduce consumer losses (Zheng et al., 2019). The more serious the information asymmetry, the more online evaluation can reduce the uncertainty of product quality (Zhang et al., 2017). The consumer’s perception of product quality will be delayed due to information asymmetry (Li et al., 2018), but online evaluation can help consumers get some product quality information in advance, thereby reducing risk and uncertainty (Yang et al., 2016). Therefore, consumers are more inclined to trust online evaluation than information provided by third-party e-commerce platform and online seller. In addition, online evaluation is not only valuable for consumers to make purchasing decisions (Fu et al., 2018) but also helpful for the online seller to attract consumers (Siering et al., 2018), because customer’s trust can significantly affect the seller’s commercial reputation (Song et al., 2019). The above research simply focus on the importance of consumer evaluation in online shopping but does not consider consumer complaint. This paper considers both consumer evaluation and complaint, and more comprehensively analyzes the role of consumer in online shopping green product quality supervision.

Generally, although some empirical research has analyzed the quality supervision of the online shopping green product, there still lacks an appropriate mathematical model to study each party’s stable strategy. Additionally, there are few studies involving multiple parties and considering consumer feedback mechanism.

Therefore, this paper considers consumer feedback mechanism and constructs a four-party evolutionary game model, which analyzes four parties’ evolutionary stable strategies, studies the conditions that make evolutionary stable strategy combination exist based on the Lyapunov’s First Method, and verifies theoretical analysis results with numerical simulation by Matlab 2020b.

MODEL ASSUMPTIONS AND CONSTRUCTION
This paper constructs a four-party evolutionary game model. The structure relationship of green product quality supervision in online shopping is shown in Figure 1.

Model Assumption
The four parties are governmental supervision department, third-party e-commerce platform, online seller, and consumer. Governmental supervision department’s strategic choice space is {SS, LS}, i.e., {Strictly Supervise, Loosely Supervise}. Third-party e-commerce platform’s strategic choice space is {SI, NSI}, i.e., {Strengthen Inspection, Not Strengthen Inspection}. Online seller’s strategic choice space is {PH, PL}, i.e., {Provide High-quality Green Product, Provide Low-quality Green Product}. Consumer’s strategic choice space is {C, NC}, i.e., {Complain, Not Complain}.

Governmental supervision department chooses to strictly supervise with the probability of \( x(0 \leq x \leq 1) \), and to loosely supervise with the probability of \( (1-x) \). Third party e-commerce platform chooses to strengthen inspection with the probability of \( y(0 \leq y \leq 1) \), and not to strengthen inspection.
with the probability of \((1 - y)\). Online seller chooses to provide high-quality green product with the probability of \(p(0 \leq p \leq 1)\), and to provide low-quality green product with the probability of \((1 - p)\). Consumer chooses to complain with the probability of \(q(0 \leq q \leq 1)\), and not to complain with the probability of \((1 - q)\).

Governmental supervision department’s cost of strict supervision is \(C_{sh}^s\). Third-party e-commerce platform’s cost of strengthening inspection is \(C_{sl}^s\), and the cost of not strengthening inspection is \(C_{pl}(C_{ph} > C_{pl} > 0)\). Online seller’s cost of providing high-quality green product is \(C_{bh}\), and the cost of providing low-quality green product is \(C_{ch}(C_{sh} > C_{ch} > 0)\).

When a green product is sold, online seller’s revenue is \(V_p\), and the third-party e-commerce platform’s revenue is \(V_g\). When third-party e-commerce platform strengthens inspection, if the online seller provides a high-quality green product, the consumer will get the utility \(R_g\), the online seller will get rewards \(J\) from the third-party e-commerce platform. If the online seller provides low-quality green product, the third-party e-commerce platform will prohibit low-quality green product and punish online seller, and the penalty is \(F\).

When the online seller provides a low-quality green product, the third-party e-commerce platform does not strengthen inspection, and the governmental supervision department chooses loose supervision, the low-quality green product will enter the market, and the consumer will undertake the loss \(L_c\). If the online seller chooses to complain, he will pay the cost \(C_c\) and receive compensation \(B_c\) from the online seller \((B_c > C_c)\). The superior department will punish the governmental supervision department, the penalty cost is \(F_g\); the governmental supervision department will also punish third-party e-commerce platform and online seller, and the penalty costs are \(F_p\) and \(F_s\), respectively. The consumer will make negative evaluation, the reputation losses of governmental supervision department, third-party e-commerce platform, and online seller are \(N_g\), \(N_p\) and \(N_s\), respectively.

When the online seller provides a low-quality green product, the third-party e-commerce platform strengthens inspection or governmental supervision department strictly supervise, a low-quality green product is prohibited from entering the market, and the consumer’s purchasing needs have not been met, the consumer’s negative utility is \(N\). When an online seller provides a high-quality green product, the consumer will make positive evaluation, and the reputation value premiums of governmental supervision department, third-party e-commerce platform, and online seller are \(R_g\), \(R_p\) and \(R_s\), respectively.

The parameters setting and their meanings are shown in Table 1.

**Model Construction**

This paper considers a consumer feedback mechanism including evaluation and complaint, and constructs an evolutionary game model. The mixed game matrix for green product quality supervision in online shopping is shown in Table 2.

**THE STABILITY ANALYSIS OF STRATEGIC CHOICES**

**The Stability Analysis of Governmental Supervision Department Strategic Choices**

The expected profit when governmental supervision department chooses strictly supervision is \(E_{GS}\). The expected profit when governmental supervision department chooses loosely supervision is \(E_{LS}\). The average expected profit of governmental supervision department is \(\overline{E}\). Replicator dynamic equation is \(F(x)\) and its first-order derivative is \(F'(x)\).

\[
E_{GS} = yp(R_g - C_{gh}) + y(1 - p)(R_g - C_{gh}) + (1 - y)p(R_g - C_{gh})
+ (1 - y)p(1 - p)(R_g - C_{gh})
\]

\[
E_{LS} = yR_g + (1 - y)pR_g - (1 - y)(1 - p)(qF_g + N_g)
\]

\[
\overline{E} = xE_{GS} + (1 - x)E_{LS}
\]

**FIGURE 1** The structure relationship of green product quality supervision in online shopping.
TABLE 1 | Parameters setting and meanings.

| Parameters | Meanings | Parameters | Meanings |
|------------|----------|------------|----------|
| $x$        | The probability of strict supervision | $1 - x$ | The probability of loose supervision |
| $y$        | The probability of strengthened inspection | $1 - y$ | The probability of unstrengthened inspection |
| $p$        | The probability of providing high-quality green product | $1 - p$ | The probability of providing low-quality green product |
| $q$        | The probability of complaint | $1 - q$ | The probability of not complaining |
| $C_{ph}$   | The cost of strict supervision | $C_{ph}$ | The cost of not strengthening supervision |
| $C_{pl}$   | The cost of providing high-quality green product | $J$ | Rewards for online seller |
| $P$        | Penalty for online seller | $V_s$ | Online seller’s revenue |
| $V_p$      | Third-party e-commerce platform’s revenue | $B_c$ | Consumer’s compensation |
| $C_c$      | Consumer’s loss after purchasing low-quality green product | $R_c$ | Online seller’s reputation value premium |
| $N_p$      | Governmental supervision department’s reputation value premium | $R_p$ | Third-party e-commerce platform’s reputation value premium |
| $N_s$      | Governmental supervision department’s reputation loss | $N_s$ | Third-party e-commerce platform’s reputation loss |
| $F_{pl}$   | Online seller’s penalty cost | $F_s$ | Governmental supervision department’s penalty cost |
| $F_{sl}$   | Third-party e-commerce platform’s penalty cost | $F_s$ | Online seller’s penalty cost |
| $N$        | Consumer’s negative utility |              |          |

TABLE 2 | Mixed game matrix for green product quality supervision.

| Online seller | Governmental supervision department |
|---------------|-------------------------------------|
|               | SS                                 | LS                                |
| $x$           | Consumer C                         | C                                 |
| $q$           | 1 - $q$                            | 1 - $q$                           |
| $y$           | PL                                 | PL                                |
| $1 - p$       | $R_s - C_{ph}$                     | $R_s - C_{ph}$                    |
| $1 - y$       | $R_c - C_{pl}$                     | $R_c - C_{pl}$                    |
| $1 - p$       | $R_s - C_{pl}$                     | $R_s - C_{pl}$                    |
| $1 - y$       | $R_c - C_{ph}$                     | $R_c - C_{ph}$                    |

$F(x) = \frac{dx}{dt} = x \left( E_{SS} - E_{LS} \right) = x(1-x) \left( E_{SS} - E_{LS} \right)$

$F'(x) = (1-2x) \left[ (1-y)(1-p) \left( R_s - qF_s - N_s \right) - C_{ph} \right]$ $\quad$ (4)

According to the stability theorem of differential equations, the probability of SS in a stable state must satisfy $F(x) = 0$ and $F'(x) < 0$.

**Proposition 1** When $q < q_0$, the evolutionary stable strategy of governmental supervision department is SS; when $q > q_0$, the evolutionary stable strategy of governmental supervision department is LS; when $q = q_0$, there is no evolutionary stable strategy.

The threshold $q_0$ satisfies $q_0 = \left[ (1-y)(1-p)(R_s - qF_s - N_s) - C_{ph} \right]/ \left( 1-y)(1-p)F_s \right]$. The threshold $q_0$ satisfies $q_0 = \left[ (1-y)(1-p)(R_s - qF_s - N_s) - C_{ph} \right]/ \left( 1-y)(1-p)F_s \right]$.

**Proof** Let $M(q) = (1-y)(1-p)(R_s - qF_s - N_s) - C_{ph}$. Take the first-order derivative of $M(q)$ with respect to $q$ yields $\partial M(q) = -\frac{\partial q}{\partial q} < 0$. Hence, $M(q)$ is negatively related to $q$. When $q < q_0$, $M(q) > 0$, $F(x) = 0$ and $F'(x) < 0$, then $x = 1$ is evolutionary stable strategy. When $q > q_0$, $M(q) < 0$, $F(x) = 0$ and $F'(x) < 0$, then $x = 0$ is evolutionary stable strategy. When $q = q_0$, $M(q) = 0$, $F(x) = 0$ and $F'(x) = 0$, no evolutionary stable strategy. The Proposition 1 shows that with the increasing of complaint probability, the evolutionary stable strategy of governmental supervision department will change from SS to LS.
According to Proposition 1, governmental supervision department’s strategic choices are shown in Figure 2.

Let $V_{g1}$ represent the probability that governmental supervision department chooses the SS strategy, and $V_{g2}$ represent the probability that governmental supervision department chooses the LS strategy.

$V_{g1} = \begin{align*}
\int_{0}^{1} & \left[ 1 - C_{gh}/(1-p)(R_{g} - N_{g}) \right] \\
& \times \left[ (1+y)(1-p)(R_{g} - N_{g}) - C_{gh} \right] \\
& \times dydx \\
= & \frac{R_{g} - N_{g}}{F_{g}} - \frac{C_{gh}}{(1-p)F_{g}} + \frac{C_{gh}}{(1-p)F_{g}} \ln \frac{C_{gh}}{(1-p)(R_{g} - N_{g})} \\
= & 1 - V_{g1} \\
= & 1 - \frac{R_{g} - N_{g}}{F_{g}} + \frac{C_{gh}}{(1-p)F_{g}} - \frac{C_{gh}}{(1-p)F_{g}} \ln \frac{C_{gh}}{(1-p)(R_{g} - N_{g})}
\end{align*}$

\[ (6) \]

Corollary 1.1 The higher the reputation value premium brought by the consumer’s positive evaluation, the higher the probability that governmental supervision department chooses the SS strategy.

\textbf{Proof} Take the first-order derivative of $V_{g1}$ with respect to $R_{g}$ yields $\partial V_{g1}/\partial R_{g} = 1/F_{g} - 1/(1-p)(R_{g} - N_{g})F_{g} > 0$. $V_{g1}$ is positively related to $R_{g}$. The probability that the governmental supervision department chooses the SS strategy is positively related to the reputation value premium brought by a consumer’s positive evaluation.

Corollary 1.1 indicates that the higher the reputation value premium brought by a consumer’s positive evaluation, the greater the influence of that consumer’s evaluation, and the higher the probability that governmental supervision department chooses the SS strategy.

\textbf{Corollary 1.2} With the increasing of strict supervision cost, the probability that governmental supervision department chooses the SS strategy will decrease.

\textbf{Proof} Take the first-order derivative of $V_{g1}$ with respect to $C_{gh}$ yields $\partial V_{g1}/\partial C_{gh} = -1/(1-p)F_{g} \left( 1 - \ln \frac{C_{gh}}{(1-p)(R_{g} - N_{g})} \right) < 0$. $V_{g1}$ is negatively related to $C_{gh}$. The probability that governmental supervision department chooses the SS strategy is negatively related to the strict supervision cost.

Corollary 1.2 indicates that the increase in strict supervision cost can discourage the governmental supervision department from choosing the SS strategy.

\section*{The Stability Analysis of Third-Party e-Commerce Platform Strategic Choices}

The expected profit when a third-party e-commerce platform chooses to strengthen inspection is $E_{SI}$. The expected profit when a third-party e-commerce platform chooses not to strengthen inspection is $E_{NSI}$. The average expected profit of third-party e-commerce platform is $E_{S}$. Replicator dynamic equation is $F(y)$ and its first-order derivative is $F'(y)$.

$E_{SI} = p(V_{p} + R_{p} - J - C_{ph}) + (1-p)(R_{p} + P - C_{ph}) \tag{8}$

$E_{NSI} = p(V_{p} + R_{p} + C_{ph}) + x(1-p)(R_{p} - C_{ph}) + (1-x)(1-p)(V_{p} - N_{p} - C_{pl} - qF_{p}) \tag{9}$

$E_{S} = yE_{SI} + (1-y)E_{NSI} \tag{10}$

$F(y) = dy/dt = y(E_{SI} - E_{S}) = y(1-y)(E_{SI} - E_{NSI})$ 

$F'(y) = (1-2y)[R_{p} + P - C_{ph} - p(J + P + R_{p} - C_{pl}) - x(1-p)(R_{p} - C_{pl}) - (1-x)(1-p)(V_{p} - N_{p} - C_{pl} - qF_{p})] \tag{11}$

$F'(y) = (1-2y)[R_{p} + P + C_{ph} - p(J + P + R_{p} - C_{pl}) - x(1-p)(R_{p} - C_{pl}) - (1-x)(1-p)(V_{p} - N_{p} - C_{pl} - qF_{p})] \tag{12}$
According to the stability theorem of differential equations, the probability of SI in a stable state must satisfy $F(y) = 0$ and $F'(y) < 0$.

**Proposition 2** When $p < p_0$, the evolutionary stable strategy of the third-party e-commerce platform is SI; when $p > p_0$, the evolutionary stable strategy of third-party e-commerce platform is NSI; when $p = p_0$, there is no evolutionary stable strategy of third-party e-commerce platform. The threshold $p_0$ satisfies $p_0 = 1 - \left(\frac{C_{ph} - C_{pl}}{P + J + (1 - x)(R_p + N_p + qF_p - V_p)}\right)$.

**Proof** Let $T(p) = R_p + P - C_{ph} - p(f + P + R_p - C_{pl}) - (1 - x)(1 - p)(V_p - N_p - C_{pl} - qF_p) - x(1 - p)(R_p - C_{ph})$.

Take the first-order derivative of $T(p)$ with respect to $p$ yields $\frac{dT(p)}{dp} = -(1 - x)(R_p + N_p + qF_p - V_p) - J - P < 0$. That is, $T(p)$ is negatively related to $p$. When $p < p_0$, $T(p) > 0$, $F(y)|_{y=1} = 0$ and $F'(y)|_{y=0} < 0$, then $y = 1$ is evolutionary stable strategy. When $p > p_0$, $T(p) < 0$, $F(y)|_{y=0} = 0$ and $F'(y)|_{y=0} < 0$, then $y = 0$ is evolutionary stable strategy. When $p = p_0$, $T(p) = 0$, $F(y) = 0$ and $F'(y) = 0$, no evolutionary stable strategy.

The Proposition 1 shows that with the increasing of the probability that online seller providing high-quality green product, the evolutionary stable strategy of third-party e-commerce platform will change from SI to NSI.

According to Proposition 2, the third-party e-commerce platform's strategic choices are shown in Figure 3. Let $V_{p1}$ represent the probability that third-party e-commerce platform chooses the SI strategy and $V_{p2}$ represent the probability that third-party e-commerce platform chooses the NSI strategy.

$$V_{p1} = \int_0^1 \left[ 1 - \frac{C_{ph} - C_{pl}}{P + J + (1 - x)(R_p + N_p + qF_p - V_p)} \right] dx dy$$

$$= 1 - \frac{C_{ph} - C_{pl}}{R_p + N_p + qF_p - V_p} \left( 1 + \ln \frac{P + J + R_p + N_p + qF_p - V_p}{C_{ph} - C_{pl}} \right)$$

$$V_{p2} = 1 - V_{p1} = \frac{C_{ph} - C_{pl}}{R_p + N_p + qF_p - V_p} \left( 1 + \ln \frac{P + J + R_p + N_p + qF_p - V_p}{C_{ph} - C_{pl}} \right) \tag{13}$$

**Corollary 2.1** With the increasing of the reputation value premium brought by the consumer’s positive evaluation or the reputation loss brought by the consumer’s negative evaluation, the probability that a third-party e-commerce platform chooses the SI strategy will increase.

**Proof** Take the first-order derivative of $V_{p1}$ with respect to $R_p$ and $N_p$ yield

$$\frac{\partial V_{p1}}{\partial R_p} = \frac{C_{ph} - C_{pl}}{R_p + N_p + qF_p - V_p} \left( 1 + \ln \frac{P + J + R_p + N_p + qF_p - V_p}{C_{ph} - C_{pl}} \right) > 0, V_{p1}$$

is positively related to $R_p$ and $N_p$. The probability that third-party e-commerce platform chooses the SI strategy is positively related to the reputation value premium brought by the consumer’s positive evaluation and the reputation loss brought by the consumer’s negative evaluation.

**Corollary 2.2** indicates that the consumer’s evaluation has an influence on the third-party e-commerce platform’s reputation, which will affect a third-party e-commerce platform’s strategic choice. With the increase of the reputation value premium or the reputation loss that a consumer’s evaluation brings to the third-party e-commerce platform, the probability that a third-party e-commerce platform chooses the SI strategy will increase. Therefore, in order to give full play to the role of consumer, we should extend the consumer evaluation channel and encourage the consumer to participate in the evaluation actively.

**Corollary 2.2** Governmental supervision department increases the penalty can encourage third-party e-commerce platform to choose the SI strategy.

**Proof** Take the first-order derivative of $V_{p1}$ with respect to $F_p$ fields

$$\frac{\partial V_{p1}}{\partial F_p} = \frac{q(C_{pl} - C_{ph})}{R_p + N_p + qF_p - V_p} \left( 1 + \ln \frac{P + J + R_p + N_p + qF_p - V_p}{C_{ph} - C_{pl}} \right) > 0, V_{p1}$$

is positively related to $F_p$. The probability that third-party e-commerce platform chooses the SI strategy is positively related to the penalty from the governmental supervision department.

**Corollary 2.2** indicates that the governmental supervision department should increase the penalty, which can promote a third-party e-commerce platform to choose the SI strategy.
The Stability Analysis of Online Seller Strategic Choices

The expected profit when an online seller chooses to provide high-quality green products is $E_{PH}$. The expected profit when an online seller chooses to provide low-quality green products is $E_{PL}$. The average expected profit of an online seller is $E_P$. Replicator dynamic equation is $F(p)$ and its first-order derivative is $F'(p)$.

\[
E_{PH} = y(V_i + R_s + J - C_{sh}) + (1 - y)(V_i + R_s - C_{sh})
\]

\[
E_{PL} = -C_{sl} - yP - (1 - y)F_i[x + (1 - x)q] + (1 - x)(1 - y)(V_i - N_s - qB_s)
\]

\[
E_P = pE_{PH} + (1 - p)E_{PL}
\]

\[
F(p) = \frac{dp}{dt} = p \left( E_{PH} - E_p \right) = p(1 - p)(E_{PH} - E_{PL})
\]

\[
F'(p) = 1 - 2p(V_i + R_s + y(J + P) + C_{sl} - C_{sh} + (1 - y)F_i[x + (1 - x)q] - (1 - x)(1 - y)(V_i - N_s - qB_s))
\]

According to the stability theorem of differential equations, the probability of PH in a stable state must satisfy $F(p) = 0$ and $F'(p) < 0$.

**Proposition 3** When $x < x_0$, the evolutionary stable strategy of the online seller is PL; when $x > x_0$, the evolutionary stable strategy of the online seller is PH; when $x = x_0$, there is no evolutionary stable strategy of the online seller. The threshold $x_0$ satisfies

\[
x_0 = 1 - y(J + P - F_i) + y(V_i + R_s + F_i + C_{sl} - C_{sh}) / (1 - y)(F_i + V_i - N_s - qF_s - qB_s)
\]

**Proof** Let $W(x) = V_i + R_s + y(J + P) + C_{sl} - C_{sh} - (1 - x)(1 - y)(V_i - N_s - qB_s) + (1 - y)F_i[x + (1 - x)q]$. Take the first-order derivative of $W(x)$ with respect to $x$ yields $\partial W(x)/\partial x = (1 - y)(1 - q)F_i + (1 - y)(V_i - N_s - qB_s) > 0$. That is, $W(x)$ is positively related to $x$. When $x < x_0$, $W(x) < 0$, $F(p)|_{p=0} = 0$ and $F'(p)|_{p=0} < 0$, then $p = 0$ is evolutionary stable strategy. When $x > x_0$, $W(x) > 0$, $F(p)|_{p=1} = 0$ and $F'(p)|_{p=1} < 0$, then $p = 1$ is evolutionary stable strategy. When $x = x_0$, $W(x) = 0$, $F(p) = 0$ and $F'(p) = 0$, no evolutionary stable strategy.

**Proposition 3** shows that with the increasing of a governmental supervision department’s strict supervision probability, the evolutionary stable strategy of the online seller will change from PL to PH.

According to Proposition 3, the online seller’s strategic choices are shown in Figure 4.

Let $V_{s1}$ represent the probability that the online seller chooses the PH strategy, and $V_{s2}$ represent the probability that the online seller chooses the PL strategy.

\[
V_{s2} = \int_0^1 \int_0^1 \left[ 1 + \frac{y(J + P - F_i) + V_i + R_s + F_i + C_{sl} - C_{sh}}{(1 - y)(F_i + V_i - N_s - qF_s - qB_s)} \right] dy dp
\]

\[
= 1 + \frac{V_i + R_s + J + P + C_{sl} - C_{sh}}{F_i + V_i - N_s - qF_s - qB_s} \ln \frac{V_i + J + P - N_s - qF_s - qB_s}{F_i + V_i + J + P + C_{sl} - C_{sh}}
\]

\[
V_{s1} = 1 - V_{s2}
\]

\[
V_{s1} = \frac{V_i + R_s + J + P + C_{sl} - C_{sh}}{F_i + V_i - N_s - qF_s - qB_s} \ln \frac{V_i + J + P - N_s - qF_s - qB_s}{F_i + V_i + J + P + C_{sl} - C_{sh}}
\]

**Corollary 3.1** With the increasing reward and penalty from a third-party e-commerce platform, the probability that the online seller chooses the PH strategy will increase.
Proof Take the first-order derivative of $V_{11}$ with respect to $J$ and $P$ yield

$$\frac{\partial V_{11}}{\partial J} = \left[ \ln \left( \frac{V_{11} + N_c - qF_s - qB_s}{V_{11} + N_s - qF_s - qB_s} \right) - 1 \left( \frac{V_{11} + P + N_s - qF_s - qB_s}{V_{11} + P + N_s - qF_s - qB_s} \right) \right] > 0$$

$$\frac{\partial V_{11}}{\partial P} = \left[ \ln \left( \frac{V_{11} + N_c - qF_s - qB_s}{V_{11} + N_s - qF_s - qB_s} \right) - 1 \left( \frac{V_{11} + N_c - qF_s - qB_s}{V_{11} + P + N_s - qF_s - qB_s} \right) \right] > 0$$

$V_{11}$ is positively related to $J$ and $P$. The probability that an online seller chooses the PH strategy is positively related to reward and penalty from the third-party e-commerce platform.

Corollary 3.1 indicates that a third-party e-commerce platform should strengthen inspection, give higher reward to the online seller who provides high-quality green products, and severely penalize the online seller who provides low-quality green products.

Corollary 3.2 The the higher the reputation value premium brought by a consumer’s positive evaluation and the reputation loss brought by a consumer’s negative evaluation, the higher the probability that an online seller chooses the PH strategy.

Proof Take the first-order derivative of $V_{11}$ with respect to $R_s$ and $N_s$ yield

$$\frac{\partial V_{11}}{\partial R_s} = \frac{1}{F_s + V_s - N_s - qF_s - qB_s} \left[ \ln \left( \frac{V_s + J + P - N_s - qF_s - qB_s}{V_s + R_s + J + P + C_{sl} - C_{sh}} \right) - 1 \right] > 0$$

$$\frac{\partial V_{11}}{\partial N_s} = \frac{V_s + R_s + J + P + C_{sl} - C_{sh}}{F_s + V_s - N_s - qF_s - qB_s} \left[ \ln \left( \frac{V_s + J + P - N_s - qF_s - qB_s}{V_s + R_s + J + P + C_{sl} - C_{sh}} \right) - 1 \right] > 0$$

$V_{11}$ is positively related to $R_s$ and $N_s$. The probability that an online seller chooses the PH strategy is positively related to the reputation value premium and reputation loss brought by the consumer’s evaluation.

Corollary 3.2 indicates that the consumer’s evaluation will affect an online seller’s reputation. After purchasing the green product, a consumer should actively make evaluation and promote the online seller to improve the green product quality.

Corollary 3.3 When the consumer purchased a low-quality green product, the higher compensation, the more an online seller tends to choose the PH strategy.

Proof Take the first-order derivative of $V_{11}$ with respect to $B_s$ yields

$$\frac{\partial V_{11}}{\partial B_s} = \frac{q(V_s + R_s + J + P + C_{sl} - C_{sh})}{(F_s + V_s - N_s - qF_s - qB_s)(V_s + J + P + N_s - qF_s - qB_s)^2} \ln \left( \frac{V_s + J + P - N_s - qF_s - qB_s}{V_s + R_s + J + P + C_{sl} - C_{sh}} \right) - \frac{q(V_s + R_s + J + P + C_{sl} - C_{sh})}{(F_s + V_s - N_s - qF_s - qB_s)(V_s + J + P + N_s - qF_s - qB_s)^2} \ln \left( \frac{V_s + J + P - N_s - qF_s - qB_s}{V_s + R_s + J + P + C_{sl} - C_{sh}} \right) > 0$$

$V_{11}$ is positively related to $B_s$. The probability that the online seller chooses the PH strategy is positively related to the compensation that the consumer gets.

Corollary 3.3 indicates that with the increasing of the compensation that the consumer gets, the probability that the online seller chooses the PH strategy will increase. Therefore, the governmental supervision department should improve the compensation and encourage consumers to complain after purchasing low-quality green products.

The Stability Analysis of Consumer Strategic Choices

The expected profit when a consumer chooses to complain is $E_c$. The expected profit when a consumer chooses not to complain is $E_{NC}$. The average expected profit of the consumer is $\overline{E_c}$. Replicator dynamic equation is $F(q)$, and its first-order derivative is $F'(q)$.

$$E_c = pR_c - x(1 - y)(1 - p)N - (1 - x)y(1 - p)N$$

$$E_{NC} = pR_c + (1 - x)(1 - y)(1 - p)(-L_s)$$

$$\overline{E_c} = qE_c + (1 - x)E_{NC}$$

$$F(q) = dq/dt = q(\overline{E_c} - E_{NC}) = q(1 - q)(E_c - E_{NC})$$

$$F'(q) = (1 - 2q)(1 - x)(1 - y)(1 - p)(N + B_s - C_s) - (1 - p)N$$

According to the stability theorem of differential equations, the probability of $C$ in a stable state must satisfy $F(q) = 0$ and $F'(q) < 0$.

Proposition 4 When $y < y_0$, the evolutionary stable strategy of consumer is $C$; when $y > y_0$, the evolutionary stable strategy of consumer is $NC$. When $y = y_0$, there is no evolutionary stable strategy of consumer. The threshold $y_0$ satisfies $y_0 = 1 - N/(1 - x)(N + B_s - C_s)$.

Proof Let $Q(y) = (1 - x)(1 - y)(1 - p)(N + B_s - C_s) - (1 - p)N$. Take the first-order derivative of $Q(y)$ with respect to $y$ yields $\partial Q(y)/\partial y = -(1 - x)(1 - p)(N + B_s - C_s) < 0$. That is, $Q(y)$ is negatively related to $y$. When $y < y_0$, $Q(y) > 0$, $F(q)|_{q=0} = 0$ and $F'(q)|_{q=0} < 0$, then $q = 0$ is evolutionary stable strategy. When $y > y_0$, $Q(y) < 0$, $F(q)|_{q=0} = 0$ and $F'(q)|_{q=0} < 0$, then $q = 0$ is evolutionary stable strategy. When $y = y_0$, $Q(y) = 0$, $F(q) = 0$ and $F'(q) = 0$, there is no evolutionary stable strategy. Proposition 4 shows that with the increasing of the probability that third-party e-commerce platform choosing SI, the evolutionary stable strategy of the consumer will change from C to NC.

According to Proposition 4, a consumer’s strategic choices are shown in Figure 5.

Let $V_{11}$ represent the probability that a consumer chooses the C strategy, and $V_{12}$ represent the probability that a consumer chooses the NC strategy.
According to the four parties’ replicator dynamic equations, we can get the following Jacobi matrix.

$$J = \begin{bmatrix}
\frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial p} & \frac{\partial F(x)}{\partial q} \\
\frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial p} & \frac{\partial F(y)}{\partial q} \\
\frac{\partial F(p)}{\partial x} & \frac{\partial F(p)}{\partial y} & \frac{\partial F(p)}{\partial p} & \frac{\partial F(p)}{\partial q} \\
\frac{\partial F(q)}{\partial x} & \frac{\partial F(q)}{\partial y} & \frac{\partial F(q)}{\partial p} & \frac{\partial F(q)}{\partial q}
\end{bmatrix}$$

**Stability Analysis When Consumer Chooses Complaint**

Consumer’s evolutionary stable strategy is complaint, when $1 - y - N/[(1 - x)(N + B_c - C_c)] > 0$ is satisfied. Substituting the pure strategy equilibrium solutions into the Jacobi matrix, we can get the eigenvalues, as shown in Table 3.

**Proposition 5** When consumer chooses complaint, $(0, 0, 1)$ is likely to become an only evolutionary stable strategy combination. At this time, the online seller chooses the PH strategy, third-party e-commerce platform chooses the NSI strategy, and the governmental supervision department chooses the LS strategy.

**Proof** According to the Lyapunov’s First Method, when consumer chooses complaint, if condition $-(R_s + N_s + B_c + F_s + C_d - C_h) < 0$ is satisfied, the Jacobian matrix’s eigenvalues of $(0, 0, 1)$ are negative, therefore, $(0, 0, 1)$ is an only evolutionary stable strategy combination. Propostion 5 shows that in order to promote an online seller to provide high-quality green products, the condition $-(R_s + N_s + B_c + F_s + C_d - C_h) < 0$ should be satisfied as much as possible. Therefore, the reputation value premium $R_s$ brought by a consumer’s positive evaluation and the reputation loss $N_s$ brought by a consumer’s negative evaluation, and the compensation $B_c$ that a consumer gets from the online seller should be increased. Besides, the
TABLE 3 | Stability analysis when consumer chooses complaint.

| Equilibrium point | Eigenvalues $\lambda_1, \lambda_2, \lambda_3$ | Sign | Stability |
|-------------------|---------------------------------|------|----------|
| (0,0,0)           | $R_p - N_p - C_{gph} R_p + N_p + P + C_{gh} - C_{gh}, -V_p R_p + N_p + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (1,0,0)           | $-P - N_p - C_{gph} R_p + P + C_{gh} - C_{gh}, -V_p R_p + N_p + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (0,1,0)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, x, x)$ | Unstable |
| (0,0,1)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (1,1,0)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (0,1,1)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (1,1,1)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |

Note: $x$ means the sign is uncertain. Condition $\exists$: $-\langle R_p + N_p + B_s + F_s + C_{gh} - C_{gh} \rangle < 0$.

TABLE 4 | Stability analysis when consumer chooses no complaint.

| Equilibrium point | Eigenvalues $\lambda_1, \lambda_2, \lambda_3$ | Sign | Stability |
|-------------------|---------------------------------|------|----------|
| (0,0,0)           | $R_p - N_p - C_{gph} R_p + N_p + P + C_{gh} - C_{gh}, -V_p R_p + N_p + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (1,0,0)           | $-P - N_p - C_{gph} R_p + P + C_{gh} - C_{gh}, -V_p R_p + N_p + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (0,1,0)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (0,0,1)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (1,1,0)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (0,1,1)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |
| (1,1,1)           | $-C_{gph} - (P + R_p + F_s + C_{gh}) V_s + R_s + J + P + C_{gh} - C_{gh}$ | $(-, +, x)$ | Unstable |

Note: $x$ means the sign is uncertain. Condition $\exists$: $R_p - P - C_{gh} < 0, V_s R_s + F_s + C_{gh} - C_{gh} < 0$. Condition $\exists$: $-\langle R_p + N_p + C_{gh} \rangle < 0$.

Stability Analysis When Consumer Chooses No Complaint

Consumer chooses no complaint, when $1 - y - N[(1 - x)(N + B_s - C_{gh})] < 0$ is satisfied. Substituting the pure strategy equilibrium solutions into the Jacobi matrix, we can get the eigenvalues, as shown in Table 4.

**Proposition 6** When a consumer chooses no complaint, $(1, 0, 0)$ and $(0, 0, 1)$ may become an evolutionary stable strategy combination.

**Proof** According to Lyapunov’s First Method, when a consumer chooses no complaint, if conditions $R_p - P - C_{gh} < 0, V_s R_s + F_s + C_{gh} - C_{gh} < 0$ are satisfied, the Jacobi matrix’s eigenvalues of $(1, 0, 0)$ are negative; if condition $-\langle R_p + N_p + C_{gh} \rangle < 0$ is satisfied, the Jacobi matrix’s eigenvalues of $(0, 0, 1)$ are negative. Therefore, $(1, 0, 0)$ and $(0, 0, 1)$ may become evolutionary stable strategy combination.

Proposition 6 shows that when a consumer chooses no complaint, the online seller may provide high-quality or low-quality green products. In order to promote an online seller to provide high-quality green quality, the condition $-\langle R_p + N_p + C_{gh} \rangle < 0$ should be satisfied as much as possible, the reputation value premium $R_p$ for an online seller brought by the consumer’s positive evaluation and the reputation loss $N_p$ for online seller brought by consumer’s negative evaluation should be increased. At the same time, in order to avoid $(1, 0, 0)$ becoming an evolutionary stable strategy combination, the conditions $R_p - P - C_{gh} < 0, V_s R_s + F_s + C_{gh} - C_{gh} < 0$ should not be satisfied, the reputation value premium $R_p$ for third-party e-commerce platform brought by consumer’s positive evaluation should be increased, third-party e-commerce platform should increases the penalty $P$ for online seller, and governmental supervision department should also increases the penalty $F_s$ for online seller.

**NUMERICAL SIMULATION ANALYSIS**

In this paper, we conduct numerical simulation by Matlab 2020b, which analyzes each factor how to influence the four parties' strategic choices. When assigning values to the parameters, we refer to the literature in some excellent journals and some statistics report data. According to consumer complaints, the China Consumers Association recovered a total of CNY 1.177 billion economic losses for consumers in 2019, and complaints about product quality problems accounted for 25.13% of all complaints. Therefore, this paper sets consumers’ compensation $B_s$ from online sellers as CNY 0.296 (25.13%*1.177) billion. According to Statistical Bulletin of National Economic and Social Development in 2019, physical products' annual online retail sales accounted for 20.7% of the total consumer products retail sales. Chinese Administration for Market Regulation’s 2019 Departmental Budget shows that the expenditure budget for market
supervision and management affairs is CNY 5.104 billion and the revenue budget is CNY 5.127 billion. Therefore, this paper sets the strict supervision cost $C_{gh}$ by governmental supervision departments as CNY $1.057 (20.7\% \times 5.104)$ billion, and third-party e-commerce platforms’ penalty cost $F_p$ as CNY $1.061 (20.7\% \times 5.127)$ billion. Let each party’s initial strategic choice be $\{0.5, 0.5, 0.5, 0.5\}$. The values of the other factors are as follows: $C_{ph} = 16$, $C_{pl} = 4$, $C_{sh} = 12$, $C_{sl} = 8$, $V_s = 20$, $V_p = 26$, $R_c = 4$, $L_c = 2$, $C_i = 4$, $N = 2$, $J = 4$, $P = 4$, $R_s = 4$, $N_s = 3$, $F_s = 8$, $F_i = 8$.

The Impact of Reputation Value Premium and Reputation Loss

Let $R_p = R_s = \{0, 4, 8\}$, $N_p = N_s = \{0, 3, 6\}$. The strategic choice and evolution process of third-party e-commerce platform and online seller are shown in Figure 6.

As can be seen from Figure 6A, when the reputation value premium or reputation loss brought by consumer evaluation are small, the stable point is $(0,0)$. The online seller is stable in providing a low-quality green product, and a third-party e-commerce platform is stable in not strengthening inspection. But, with the increasing of reputation value premium or reputation loss, the greater the influence on the online seller and third-party e-commerce platform, the stable point turns into $(0,1)$. The online seller’s evolutionary stable strategy is to provide high-quality green product, and a third-party e-commerce platform’s evolutionary stable strategy is not to strengthen inspection (Figures 6B,C). We can get that the increase in reputation value premium or reputation loss can promote the online seller to provide a high-quality green product.

The Impact of Reward and Penalty

Let $R_p = R_s = 4$, $N_p = N_s = 3$, $C_{ph} = 6$, $C_{pl} = 2$, $V_s = 12$. We change the online seller’s reward and penalty from a third-
party e-commerce platform, and let $I = \{0, 30, 60\}, \ P = \{0, 30, 60\}, \ \text{then the strategic choice and evolution process of the four parties are shown in Figure 7.}$

As can be seen from Figure 7A, when an online seller’s reward and penalty from third-party e-commerce platform is zero, it means that the third-party e-commerce platform has chosen not to strengthen inspection. At this time, $p = 0$, an online seller provides low-quality green products. However, with increasing of the reward and penalty, the online seller’s strategic choice fluctuates, and a third-party e-commerce platform adjusts accordingly. Finally, $p = 1$, the online seller has gradually stabilized to provide high-quality green products, at this time, a third-party e-commerce platform has gradually stabilized to not strengthen inspection. This fully shows that the third-party e-commerce platform should give an online seller the higher reward or penalty, which can encourage the online seller to improve the green product quality.

**The Impact of Consumer Complaint**

Let $R_p = R_s = 4, \ N_p = N_s = 3, \ C_{ph} = 6, \ C_{pl} = 2, \ V_s = 12, \ J = P = 4$. We change the probability that a consumer chooses complaint, and let $q = \{0, 0.5, 1\}$. Then the strategic choice and evolution process of the four parties are shown in Figure 8.

As can be seen from Figure 8, when the probability that a consumer chooses complaint is low (Figure 8A), there is no evolutionary stable strategy. With the increasing of the probability that a consumer chooses complaint, the strategic choices of online seller and third-party e-commerce platform fluctuates (Figure 8B). When a consumer’s strategic choice has gradually stabilized to choose complaint, the online seller will provide high-quality green products, and the third-party e-commerce platform will stabilize to not strengthen inspection (Figure 8C). Therefore, the consumer should raise rights protection awareness and actively complain about the online seller’s illegal behavior.

**The Impact of Penalty Cost**

As can be seen from Figure 9, when the penalty cost is low, the stable point is (0,0,0), governmental supervision department chooses to loosely supervise, third-party e-commerce platform chooses to strengthen inspection, and online seller chooses to provide low-quality green product (Figures 9A,B). With the increasing of the penalty cost, the stable point turns into (0,0,1), governmental supervision department has stabilized to loosely supervise, the third-party e-commerce platform has stabilized to not strengthen inspection, and the online seller has gradually stabilized to provide high-quality green product. Therefore, a governmental supervision department should increase the penalty to promote that the online seller provide high-quality green product.

**SUMMARY**

**Conclusion and Policy Implications**

This study describes that with the rapid e-commerce development, consumers pay more attention to sustainability, and a growing number of consumers prefer to purchase green products online. This paper considers consumer feedback mechanisms including evaluation and complaint and constructs four-party evolutionary game model, which analyzes four parties’ evolutionary stable strategies. Further, it studies the conditions that make evolutionary stable strategy combination exist based on Lyapunov’s First Method. Finally, this paper verifies theoretical analysis results with numerical simulation by Matlab 2020b. The main conclusions are as follows.

The consumer’s evaluation will affect an online seller’s reputation and promote the online seller to provide high-quality green product. When the reputation value premium or reputation loss brought by consumer evaluations are small,
the online seller is stable in providing low-quality green product. But, with the increasing of reputation value premium or reputation loss, the online seller’s evolutionary stable strategy will turn into providing a high-quality green product. Therefore, third-party e-commerce platform should implement the reputation rating system based on consumer evaluation, which can be a constraint and incentive for online sellers, because it will directly affect the online seller’s search rankings and promotion positions. And when the online seller provides low-quality green product, the consumer should make a negative evaluation.

Third-party e-commerce platform increases reward and penalty for the online seller can help improve online shopping green product quality. When an online seller’s reward and penalty from third-party e-commerce platform are small, the online seller will provide a low-quality green product. However, with increasing of the reward and penalty, the online seller has gradually stabilized to provide high-quality green product. Therefore, the third-party e-commerce platforms should require the online seller to pay deposits. When an online seller harms the consumer rights, third-party e-commerce platforms can deduct the deposit as punishment for the online seller. Practice has proved that this method can indeed play an effective role in restraining the online seller’s behavior.

Consumer complaints can urge an online seller to improve green product quality. With the increasing of the probability that a consumer is choosing complaint, the online seller will provide high-quality green product. Therefore, the governmental supervision department should improve the consumer complaint channel. The consumer should actively raise awareness of rights protection and incentive to complain or report to a governmental supervision department when the online seller provides low-quality green product; at this time, the governmental supervision department will punish the online seller severely. The most important thing is that an online seller can take on social responsibilities, continue to innovate product, and provide the consumer with high-quality product (Abbas et al., 2020).

**Limitation and Future Direction**

This paper provides pathways and direction for future research. It emphasizes effective supervision strategies for online shopping green product quality and constructs a four-party evolutionary game model. The study applies a mathematical model approach in this research. It considers consumer feedback mechanism (evaluation and complaint, and analyze the evolutionary stable strategies) and examines the existence of an evolutionary condition based on Lyapunov’s First Method. It offers proposals for how to design effective green product quality and its supervision strategies when existing online shopping.

Concerning the study limitations, forthcoming studies can examine different factors models in different regions and countries. They can use different questionnaires for different variables, filled, and seek feedback from different respondents to eliminate the impact of standard method deviations on research results. Future studies can examine large sample sizes with different factors to draw exciting results. Besides, in the future, this paper can expand the model from the following aspects. It can construct a dynamic game model under asymmetric information and consider the game order and analyze each party’s strategic choice in the long-term repeated game.

**DATA AVAILABILITY STATEMENT**

The original contributions presented in the study are included in the article-supplementary material, further inquiries can be directed to the corresponding author.

**AUTHOR CONTRIBUTIONS**

HH writes the manuscript and data analysis, SZ contributed in the revision, LZ revises the manuscript and solves the model.
FUNDING

This work was supported by the National Social Science Fund of China under grant Nos. 20BGL272 and 21ZDA024.

ACKNOWLEDGMENTS

The authors are grateful to the referees for their valuable comments and their help on how to improve the quality of our paper.

Hong, Z. F., and Guo, X. L. (2019). Green Product Supply Chain Contracts Considering Environmental Responsibilities. Omega 83, 155–166. doi:10.1016/j.omega.2018.02.010

Kaynak, H., and Hartley, J. L. (2008). A Replication and Extension of Quality Management into the Supply Chain. J. Operations Manage. 24 (4), 468–489. doi:10.1016/j.jom.2012.02.002

Li, B., Wen, D. C., and Shi, X. D. (2015). Research on Product Quality Control in Chinese Online Shopping: Based on the Uncertainty Mitigating Factors of Product Quality. Total Qual. Manage. Business Excell. 26 (5–6), 602–618. doi:10.1080/14783636.2013.865917

Li, D., Nagurney, A., and Yu, M. (2018). Consumer Learning of Product Quality with Time Delay: Insights from Spatial price Equilibrium Models with Differentiated Product. Omega 81, 150–168. doi:10.1016/j.omega.2017.10.007

Li, Y. P., Wen, D. C., and Sun, X. J. (2018). Quality Supervision Game between Government and Online Shopping Platforms. Total Qual. Manage. Business Excell. 29 (9–10), 1–13. doi:10.1080/14783636.2018.1487617

Liu, D., Xiao, X., Li, H., and Wang, W. (2015). Historical Evolution and Benefit–Cost Explanation of Periodical Fluctuation in Coal Mine Safety Supervision: An Evolutionary Game Analysis Framework. Eur. J. Oper. Res. 243 (3), 974–984. doi:10.1016/j.ejor.2014.12.046

Loureiro, S. M. C., Sardinha, I. M. D., and Rejinders, L. (2012). The Effect of Corporate Social Responsibility on Consumer Satisfaction and Perceived Value: The Case of the Automobile Industry Sector in Portugal. J. Clean. Prod. 37, 172–178. doi:10.1016/j.jclepro.2012.07.003

Maryam, H., and Hossein, Z. (2018). Green Product Development and Environmental Performance: Investigating the Role of Government Regulations. Int. J. Prod. Econ. 204, 395–410. doi:10.1016/j.ijpe.2018.08.012

Mavlanova, T., Benbunan-Fich, R., and Koufaris, M. (2012). Signaling Theory and Information Asymmetry in Online Commerce. Inf. Manage. 49 (5), 240–247. doi:10.1016/j.infforum.2012.05.004

Mubeen, R., Han, D., Abbas, J., and Hussain, I. (2020). The Effects of Market Competition, Capital Structure, and CEO Duality on Firm Performance: A Mediation Analysis by Incorporating the GMM Model Technique. Sustainability 12 (8), 3480. doi:10.3390/su12083480

Park, J., and Ju, B. G. (2016). Hierarchical Outcomes and Collusion Neutrality on Networks. Eur. J. Oper. Res. 254 (1), 179–187. doi:10.1016/j.ejor.2016.03.011

Rong, J. M., and Zhu, L. (2020). Cleaner Production Quality Regulation Strategy of Pharmaceutical with Collusive Behavior and Patient Feedback. Complexity 2020, 1–15. doi:10.1155/2020/1920523

Sana, S. S. (2020). Price Competition Between Green and Non-Green Products Under Corporate Social Responsible Firm. J. Retailing Consumer Serv. 55, 102118. doi:10.1016/j.retcomser.2020.10.004

Seung, H. Y. (2014). Product Quality and Return Policy in a Supply Chain under Risk Aversion of a Supplier. Int. J. Prod. Econ. 154 (3), 146–155. doi:10.1016/j.ijpe.2014.04.012

Shang, G. Z., Pekgun, P., Ferguson, M., and Gallbreth, M. (2017). How Much Do Online Consumers Really Value Free Product Returns? Evidence from eBay. J. Operations Manage. 53-56, 45–62. doi:10.1016/j.jom.2017.07.001

Siering, M., Muntermann, J., and Rajagopalan, B. (2018). Explaining and Predicting Online Review Helpfulness: The Role of Content and Reviewer-Related Signals. Decis. Support Syst. 108, 1–12. doi:10.1016/j.dss.2018.01.004

Song, H. J., Ruan, W., and Park, Y. (2019). Effects of Service Quality, Corporate Image, and Customer Trust on the Corporate Reputation of Airlines. Sustainability 11 (12), 1–14. doi:10.3390/su11123302

Subramanian, U., and Rao, R. C. (2016). Leveraging Experienced Consumers to Attract New Consumers: An Equilibrium Analysis of Displaying deal Sales by Daily deal Websites. Manage. Sci. 62 (12), 3555–3575. doi:10.1287/mnsc.2015.2298

Tao, Z., Gang, L., and Keung, L. K., (2018). Information Disclosure Strategies for the Intermediary and Competitive Sellers. Eur. J. Oper. Res. 271 (3), 1156–1173. doi:10.1016/j.ejor.2018.06.037
Wang, X. Y., Ming, M. M., and Zhang, Y. Q. (2020). Are “People” or “Animals” More Attractive? Anthropomorphic Images in Green-product Advertising. J. Clean. Prod. 276, 122719. doi:10.1016/j.jclepro.2020.122719

Yang, J., Sarathy, R., and Lee, J. (2016). The Effect of Product Review Balance and Volume on Online Shoppers’ Risk Perception and Purchase Intention. Decis. Support Syst. 89, 66–76. doi:10.1016/j.dss.2016.06.009

Zhang, J. Q., Cao, Q. N., and He, X. L. (2019). Contract and Product Quality in Platform Selling. Eur. J. Oper. Res. 272 (3), 928–944. doi:10.1016/j.ejor.2018.07.023

Zhang, X., Ma, L., and Wang, G. S. (2017). Investigating Consumer Word-Of-Mouth Behavior in a Chinese Context. Total Qual. Manage. Business Excell. 30 (5-6), 579–593. doi:10.1080/14783363.2017.1317587

Zheng, H. C., Xu, B., and Lin, Z. X. (2019). Seller’s Creditworthiness in the Online Service Market: A Study from the Control Perspective. Decis. Support Syst. 127, 113–118. doi:10.1016/j.dss.2019.113118

Zhou, L., Wang, W., and Xu, J., (2018). Perceived Information Transparency in B2C E-Commerce: an Empirical Investigation. Inf. Manage. 55 (7), 912–927. doi:10.1016/j.im.2018.04.005

Zhu, L. L. (2020). Supply Chain Product Quality Control Strategy in Three Types of Distribution Channels. PloS One 15 (4), e0231699. doi:10.1371/journal.pone.0231699

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Publisher’s Note:** All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

**Copyright © 2021 He, Zhang and Zhu. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.**