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Research Article

Evolutionary Game Analysis of Online Shopping Quality Control: The Roles of Risk Attitude and Government Supervision

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The product quality issues of online shopping have not been effectively solved with the rapid development of electronic commerce in China. Faced with the quality issues of online shopping, the main entities, such as online platforms and online sellers, should cooperate to control and assure compliant quality. The adverse selection of buyers caused by information asymmetry and the moral hazard of sellers aggravated by bilateral markets make the quality management of online shopping have a high degree of uncertainty and complexity. This study constructs an evolutionary game model to discuss the dynamic process of the quality behaviours of members and analyse the key triggers of the evolutionary directions in online shopping. By using numerical simulation analysis, the influences of government supervision intensities on the evolution trend of members' quality behaviours are analysed with various risk attitude combinations in various cases. The current research finds that (1) the decrease of the quality control cost and the increase of the government's benchmark fine are conducive to increasing the platform's controlling probability; (2) the decrease of the proportion of rent and the increase of sellers' fraud cost and the government's benchmark fines are conducive to increasing the seller's compliance probability; (3) when both the platform and seller are unwilling to make efforts for quality assurance, risk-seeking members make the seller gradually choose to provide compliant products; and (4) when the members are all risk-seeking, strengthening government supervision will help promote the transition of members' behavioural choices in a benign direction. This paper enriches the theoretical research studies on both online product quality control and government-led social governance system of quality. Suggestions for government supervision and e-commerce entities are also provided for quality assurance and improvement.

1. Introduction

Recently, electronic commerce has developed rapidly in China, but the product quality issues have not been solved effectively. The rapid emergence of new online transaction forms such as online live commerce has increased the difficulty of online transaction quality control while creating new value. The quality supervision gap gives unscrupulous businesses opportunities to conduct false propaganda and sell fake and shoddy products. According to the report released by https://www.100ec.cn, the quality issues and fake products are still the hot issues of online shopping complaints in the first half of 2020 (https://www.100ec.cn/zt/2020yhtsbg/). The product quality in the online transaction has always been a problem that plagues consumers. It is a Gordian knot that major stakeholders such as government regulators, online shopping platforms, online sellers, and consumers have been dealing with.

In the process of online transactions, the online sellers (hereinafter referred to as the Seller) are the providers of products and corresponding services in online shopping activities. They take responsibility for ensuring product quality. The online shopping platforms (hereinafter referred to as the Platform), as the key party of the online shopping market, should bear the main responsibility for quality control of online shopping products. In accordance with *E-commerce Law of the People's Republic of China*, e-commerce platform operators should follow the principles of openness, fairness, and justice, formulate platform service agreements and transaction rules, and clarify their rights and obligations in terms of entering and exiting the platform, guaranteeing the quality of products and services, protecting consumer rights, and protecting personal information. In this paper, we call the members' behaviours about quality as quality behaviours. As for the Seller, quality behaviours refer to whether to provide the compliant products for the customers. As for the Platform, quality behaviours refer to whether to control the sellers' quality behaviours.

In reality, however, the Seller and the Platform may not fulfil their quality responsibilities, causing quality risks of online shopping. Due to the hidden and virtual nature of online sellers, it is difficult for consumers to grasp the true quality of products before buying, which leads to adverse selection under information asymmetry eventually [1]. In order to mitigate the hazards of adverse selection, the consumers pin their hopes on online shopping platforms as quality intermediaries to help consumers identify quality information and avoid counterfeit and shoddy products. However, online shopping platforms, as an economic organization in the two-sided market, will not be completely biased towards consumers. Some platforms indulge the behaviours of the online sellers and even collude with them to defraud consumers in quality control. Only relying on the Platform quality control often leads to issues such as high cost, inefficiency, and inadequate control [2]. It also requires the government to supervise the quality behaviours of the Seller and the Platform to ensure and improve the quality of online shopping products.

The promotion of product quality by the government is a hot topic in the theoretical and practical research field [3, 4]. The government supervision policy plays a vital role on product quality, especially in the online virtual trading process. The government usually takes mandatory measures and inceptive policies to supervise quality activities. The former generally includes penalty, administrative licensing, and law, while the latter includes tax and subsidy [4, 5]. In practice, however, due to the lack of government regulatory agencies and functions, the government has a certain degree of lag in the quality supervision of online shopping products and has not established a quality supervision mechanism completely suitable for the online shopping market. In addition, due to the insufficient government supervision and punishment of online shopping products, it has not fundamentally affected the quality of online shopping products. Therefore, this study takes government quality supervision as a key factor and explores its impacts on online shopping product quality control.

Traditional online shopping quality control ignores the competitive and strategic attributes of the Seller's and the Platform's quality behaviours in the uncertain e-commerce market environment. In fact, the uncertainty of quality is not only affected by the uncertainty of the production and delivery process but also affected by the risk attitude of the participants [6]. Most of the existing literature studies study the risk attitudes of game participants in the field of supply chain quality control [7–9], but there are few discussions on the risk attitudes of quality control game subjects in the online shopping situation. In particular, there is no research that combines government quality supervision and members' risk attitudes to consider their influences on the evolution of online shopping quality control.

Based on the above considerations, this paper focuses on the product quality control considering members' risk attitudes under government supervision in the context of online shopping. In order to reflect the interactivity and dynamics of the participants' quality behaviours, this paper establishes an evolutionary game model for quality control. The main innovations may be reflected in the following three points: first, this paper considers the effects of the Platform's and the Seller's risk attitudes and the interaction between them by constructing risk revenue functions. Secondly, this paper discusses the heterogeneous effects of government supervision intensity on online shopping quality control. By using numerical simulation analysis, the influences of government supervision intensities on the evolution trend of members' quality behaviours are obtained with various risk attitude combinations in various cases. Finally, this article comprehensively discusses the key factors that affect the outcomes of the online shopping quality control game from the perspective of dynamic evolution.

The rest of this paper is organized as follows: Section 2 reviews the research studies on quality control under the government supervision and with risk attitudes. Section 3 introduces the basic assumptions and parameters of the game models and analyses the evolutionary behaviours of the Platform and the Seller. Section 4 performs a numerical simulation and discusses the effects of variables. Section 5 provides the conclusions, implications, and future research.

2. Literature Review

This paper is closely related to two research streams: (1) online shopping quality game under the government supervision and (2) quality control game considering risk attitudes.

2.1. Online Shopping Quality Game under the Government Supervision. There are only a few research studies discussing the product quality control of online shopping under the government supervision. To solve the quality issues in online shopping, Li et al. [1] built the model of three-level product quality control of Chinese online shopping, clarifying the responsibilities of entities and emphasizing the role of government supervision. Fu [10] established the evolutionary game of the online shopping platform and seller with consideration of players' losses caused by government penalty. The results showed that the punishment of the platform and the seller who violated the relevant supervision could prompt the platform and the seller to improve the quality of online shopping products. Li et al. [2] designed a quality game model between the online shopping platform and the government and explained the essential role of government supervision in online shopping quality assurance. He and Zhu [11] focused on the green product quality in online shopping and explored the impact of consumer feedback on the three-party quality evolutionary game of "online shopping platform-online seller-government regulatory authority," and found that the government should encourage consumers to complain, improve the green product certification mechanism, and severely punish violations in the transaction process to control the green product quality of online shopping. He et al. [12] analysed the impacts of quality dropping rate and products' deterioration rate on the company's delivery time decisions, pricing and inventory decisions in a dual-channel supply chain that combined online direct sale channel and traditional offline channel.

To expand the research horizon, we break through the limitations of the research context and review the existing research studies on the game of government quality supervision. Prior research studies on the game of government quality supervision are mainly divided into two categories.

One is to regard the government as a participant in the game and study the game relationships between two or three parties, such as the government and the online shopping platform [2], the government and the manufacturing enterprise [13–17], the government and the third-party institution [18]. Zhu, et al. [14] designed a static game model of establishing quality management system between the government and the enterprise. Yu and Liu [15] constructed a pure-strategy game model and a mixed-strategy game model between the government and production enterprises and found that the effectiveness of government quality supervision depended on the additional expected benefits for the enterprise from producing inferior products, the punishment and the government's supervision cost. Liu and Yu [19] established a rent-seeking game model for green products in which the government, the third-party certification agency, and the company participated. They found that the government could effectively avoid the rent-seeking behaviours by improving the supervision capability, reducing the supervision cost, and increasing the penalty. Zhu and Guo [16] established a game model between the government and the cold-chain food company and found that the probability of company providing high-quality food was related to the government supervision cost, the punishment of the company, and the punishment of the government's supervisory department for dereliction. Cao et al. [17] established a symmetrical game model between individual and group to discuss the failure of government supervision and the government's best supervision strategy with the increase of the number of food companies. Yu and Liu [18] constructed an evolutionary game model between the government and third-party inspection agency and found that the government supervision cost, the penalty, and the third-party inspection cost were the key factors affecting the evolutionary game system. Yu et al. [20] established a three-stage game model among the government, the supplier, and the processor in a two-stage food supply chain considering the government subsidy. They gave feasible area for government subsidy and discussed the impact of government subsidy on food safety investment, pricing, and market share. He et al. [21] designed a game model of the dual-channel closed-loop supply chain, deriving the government's optimal subsidy level under different channel structures.

The other believes that the revenue of the government as a rule maker and supervisor is difficult to quantify directly. Therefore, the government supervision can only be considered as an external factor that affects the quality supervision game. Xu et al. [22] established an evolutionary game model of food quality investment between the supplier and the manufacturer considering the government punishment mechanism and subsidy mechanism and found that government supervision could curb free-riding in the food supply chain. Mu and Ma [23] designed a food supply chain information sharing model with government punishment. Gao [24] established an asymmetric evolutionary game model between agricultural product suppliers and found that the government could encourage and constrain suppliers to invest in product quality and safety by subsidy and penalty. Yang et al. [25] established a food supply chain quality evolutionary game model under government supervision and found that only when the punishment was sufficiently strong, the supplier and the producer could choose to improve the food quality.

Through the analysis of the above literature, it is found that there is a lack of research studies on government quality supervision in the context of online shopping. The research studies on the government quality supervision game can be roughly divided into two categories: the government directly participates in the game and the government acts as an external factor without participating in the game. In addition, due to the dynamic nature of market development, research studies on government quality supervision show a trend from static views to dynamic views. This study considers the government supervision as an external factor in the game between the Platform and the Seller and discusses the influence of government supervision intensity and benchmark fine on the members' strategic choices in an evolutionary view.

2.2. Quality Control Game considering Risk Attitudes. Both prospect theory and utility theory believe that risk attitudes can affect decision-making [26, 27]. Many previous studies analysed and discussed the impacts of members' risk attitudes on the performance in some areas such as supply chain [8, 9, 28, 29], environment protection [30], and financial policy [31, 32]. Risk attitudes include risk-seeking, risk-aversion, and risk neutrality. Compared with risk neutrality, risk-seeking and risk-aversion represent the preference for higher-risk and lower-risk options, respectively [31].

The prior research studies on quality control games with risk attitudes are mostly about supply chain topics. Agrawal and Seshadri [26] designed mutually beneficial risk-sharing contracts in the supply chain to avoid inefficiencies caused by retailers' risk-averse attitude. Tapiero and Kogan [6] established a risk-neutral game model and added risk qualifications to the quality control decision-making of supply chain members. Tapiero [33] established a cooperation framework for supply chain strategic quality control and assurance using the Neyman–Pearson quantile risk theory. Xie et al. [34] discussed the risk-averse quality investment decisions of the manufacturer's Stackelberg, the vertical integration, and the supplier's Stackelberg in the make-to-order supply chain. Liu and Wang [7] established a logistics service supply chain quality control game model considering the risk attitudes and analysed the effects of different risk attitude combinations on the supervision probability of service integrator and the compliance probability of service provider. Avinadav et al. [35] analysed the impacts of members' risk-sensitive behaviours on quality investment strategies under uncertain demand in mobile application supply chain and found that risk-seeking developers were more likely to increase investment in mobile application quality. Deutsch and Golany [36] analysed the influences of risk-averse and risk-neutral behaviours on the results of the inspection game and found that the agent's risk attitude could affect the equilibrium utilities and equilibrium strategies of both parties in the game, and the inspector's risk-averse attitude could only affect the inspector's equilibrium utilities and agent's equilibrium strategy. Chernonog et al. [9] developed a quality investment game model of virtual-product supply chain with the risk attitudes. Hu and Meng [37] discussed the impacts of participants' risk tolerance (risk-seeking and risk-aversion) in the mobile game supply chain on the quality effort decisions of the developer and the sale effort decisions of the seller. Yu et al. [20] established a game model of the food supply chain composed of the supplier and processor under the government supervision and found that both processor's quality investment and the supplier's profit increased with the increase of the degree of the processor's risk-aversion.

It can be found that few research studies consider the risk attitudes of participating entities in the context of online shopping [38]. Although other related research studies considered participants' risk attitudes, they seldom discussed the heterogeneity of participants' decision-making under different risk attitude combinations. This study considers the different risk attitude combinations of the Platform and the Seller as different cases and explores the impacts of changes of key decision-making parameters (such as the intensity of government supervision) on changes of players' decision-making.

Compared with the research studies on both government quality supervision and quality game with risk attitudes, the theoretical contributions of this study are mainly reflected in the following aspects. First, the research studies on the government quality supervision mechanism in the context of online shopping are still insufficient. This study analyses the evolution of quality behaviours of the Platform and the Seller in online shopping under government supervision from a dynamic perspective. Second, prior studies often consider the role of government quality supervision in two ways, one is to use the penalty parameter (or subsidy parameter) as the external parameters to discuss its impact on quality behaviours and the other is to consider the government as a participant in the game, and discuss the impact of its quality supervision behaviour choice (supervision or nonsupervision) on the other participants' decisions. Few studies consider the role of government supervision intensity. This study refines the parameters of the government punishment mechanism and considers the government supervision intensity as an external factor in addition to the benchmark fine, which enriches the knowledge system of the influence of government supervision on the members' quality behaviour decisions. Third, the prior research studies on the online shopping quality supervision game did not consider the role of participants' risk attitudes. This study considers the impact of the combinations of the Platform's and Seller's risk attitudes on the evolution of quality behaviours in the context of online shopping quality supervision. At the same time, this study considers both government supervision intensity and risk attitude combination and discusses the influence of government supervision intensity on the quality control with different risk attitude combinations of the members.

3. Quality Game Model of Platform and Seller under Government Supervision

We establish two quality control game models. First, we construct the quality game model of the Platform and the Seller without risk attitude (Model I). Second, we construct the risk revenue functions of the Platform and the Seller and then establish the final quality control game model (Model II).

3.1. Quality Game Model without Risk Attitudes. With reference to previous research studies, such as the quality control game model in Li et al. [2], we design the game model of the Platform and the Seller under government supervision without risk attitude.

Firstly, we assume that there are two players, the Platform and the Seller, in this game. The Seller benefits from providing products and services for customers, and the quality of the products and services they deliver depends on the Seller's efforts. The Platform does not sell products directly to end customers but is responsible to control the quality of the products and services as a medium for transactions. The five important assumptions of this model are as follows:

> Assumption 1: we assume that the Seller's basic revenue is B_s. The Seller can fully control the quality of the products sold. Thus, the Seller has two behavioural choices. One is providing compliance products and services for customers. The other one is providing noncompliant products and services for customers, i.e., S_1 = (compliance, not compliance). Providing compliant products in this study means the Seller needs to meet the two conditions at the same time: (1) the products provided by the Seller meet the objective requirements of the government's laws and supervision, the Platform, and other social forces mandatory requirements; (2) the quality of the products should be consistent with the Seller's commitment. Since products in a broad sense include physical products and virtual products, products and services are collectively referred to as products after that. When the Seller chooses to sell the compliant product, the Seller needs

to strictly select the supplier channel to ensure the high quality of the product, pay higher purchase price, inspect the sold product, and provide good after-sales service. The Seller's effort on quality n_i determines the cost of providing the product $C_s(n_i)$, in which $i = 1, 2$ ($i = 1$ when the Seller provides a compliant product; $i = 2$ when the Seller provides a noncompliant product). When the Seller provides a compliant product, the quality effort is n_1, and the cost of providing the product is $C_s(n_1)$. When the Seller provides a noncompliant product, the quality effort is n_2, and the cost of providing the product is $C_s(n_2)$.

Assumption 2: the Seller's efforts on quality may attract more end customers to trade to obtain total additional revenue $l(n_i) = h(n_i) + \varepsilon$. In this function, $h(n_i)$ indicates an increasing function of the Seller's quality effort. $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ shows the influence of external environment factor on total additional revenue. When the Seller provides a compliant product, total additional revenue is $l(n_1)$, and when the Seller provides a noncompliant product, the total additional revenue is $l(n_2)$. It is worth noting that the total additional revenue $l(n_i)$ is shared by the Seller and the Platform. The Platform gets its own additional revenue $rl(n_i)$ from the total additional revenue, and r is the revenue coefficient, $0 < r < 1$. Thus, $(1 - r)l(n_i)$ represents the Seller's own additional revenue.

Assumption 3: we assume the basic revenue of the Platform is B_p. The Platform has two behavioural choices: controlling or not controlling the quality of products and services sold by the Sellers, i.e., $S_2 = (\text{Control}, \text{Not control})$. When the Platform chooses to control the Seller and the quality of their products, it is necessary to take some affective measures, such as conducting strict audits of the settled Sellers, sampling the online transaction products, tracking online shopping behaviour, and handling commodity quality disputes and complaints. The level of quality control of the Platform is assumed to be $m (0 \leq m \leq 1)$, and the relevant cost required for these control measures is $C_p(m) = g(m) + \eta$ in which $g(m)$ is the increasing function of level of quality control m, and $\eta \sim N(0, \sigma_\eta^2)$ indicating the influence of the external environment factor on quality control cost. ε and η are the parameters which are independent of each other. Due to different levels of control by the Platform, the Seller's noncompliance behaviour cannot always be found by the Platform. Once the Seller's noncompliance behaviour is found, the Seller will face the punishment from the Platform, which is $mF (F > 0)$.

Assumption 4: it is assumed that the government mainly supervises the quality of online shopping products through random inspection and fines for illegal participants. The government can discover some quality violations of the Seller and the Platform through approaches and tools such as quality risk confirmation, quality monitoring plans, online sampling, sample inspection, evaluation, and processing of quality monitoring results. When the Seller provides noncompliant products, the government fines for the Seller is αM_1. The parameter α is the government's supervision intensity for the Seller $(0 \leq \alpha \leq 1)$. $M_1 (M_1 > 0)$ represents the government benchmark fine for the Seller, which is static in short run and dynamic in long run. If the Platform does not control the product quality, the government quality supervision organization will punish the Platform, and the penalty loss of the Platform is βM_2. The parameter β is the government's supervision intensity for the Platform $(0 \leq \beta \leq 1)$. $M_2 (M_2 > 0)$ represents the government benchmark fine for the Platform, which is static in short run and dynamic in long run.

Assumption 5: it is assumed that the Platform and the Seller are boundedly rational.

Table 1 includes the parameters and descriptions for Model I.

Based on the above assumptions, we obtain the payoff matrix without risk attitudes summarized in Table 2.

3.2. Quality Game Model with Risk Attitudes. The risk attitudes of the Platform and the Seller will influence the control probability of the Platform and the compliance probability of the Seller through changing the expected revenues of both of the two considering risks. Based on the previous research studies and facts in online shopping, we propose some important assumptions as follows:

Assumption 1: risk attitudes of Platform and Seller are A_p and A_s, respectively, with three possible types: risk-seeking (when $A_p < 0$ or $A_s < 0$), risk-aversion (when $A_p > 0$ or $A_s > 0$), and risk-neutral (when $A_p = 0$ or $A_s = 0$) [7].

Assumption 2: compared with risk-neutral attitude, risk-seeking attitude will bring risk returns to decision-makers, while risk-averse attitude will bring risk losses to decision-makers [39]. For example, risk-seeking platforms and sellers always adopt aggressive strategies, which means that they dare to take certain risks, such as market risks and financial risks, to provide customers with high value-added products and services. They take high-quality risks while also obtaining high profits. In contrast, risk-averse decision-makers always adopt conservative strategies and therefore miss many opportunities for profit. Therefore, compared with risk-neutral decision-makers, risk-seeking decision-makers will get higher risk returns because they dare to take high risks, while risk-averse decision-makers will lose the opportunity to obtain risk rewards due to risk-aversion, and they need to accept inevitable opportunity loss. The level of risk gain (loss) is positively correlated with the level of risk-seeking (risk-aversion) [7, 39].

Assumption 3: the level of risk loss (gain) gets positively correlated with the fluctuations in the external environment factor [7].

Table 1: Symbols and descriptions of parameters for Model I.

Symbol	Description
B_s	The Seller's basic revenue
n_i	The Seller's effort level on quality, $i = 1, 2$ ($i = 1$ when the Seller provides a compliant product; $i = 2$ when the Seller provides a noncompliant product), $n_1 > n_2$
$C_s(n_i)$	The cost of the Seller on providing the product. $C_s(n_1)$ is the cost of providing the product when the Seller provides a compliant product, while $C_s(n_2)$ is the cost of providing the product when the Seller provides a noncompliant product
$l(n_i)$	Total additional revenue, $l(n_i) = h(n_i) + \varepsilon$. $h(n_i)$ is an increasing function of the Seller's quality effort. $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ shows the influence of external environment factor on total additional revenue. $l(n_1)$ is total additional revenue when the Seller provides a compliant product, and $l(n_2)$ is total additional revenue when the Seller provides a noncompliant product
r	The revenue coefficient of Platform from total additional revenue, $0 < r < 1$
α	The government's supervision intensity for the Seller, $0 \le \alpha \le 1$
β	The government's supervision intensity for the Platform, $0 \le \beta \le 1$
M_1	Government benchmark fine for the Seller, $M_1 > 0$
M_2	Government benchmark fine for the Platform, $M_2 > 0$
B_p	The Platform's basic revenue
m	The level of quality control of the Platform, $0 \le m \le 1$
$C_p(m)$	The relevant cost of the Platform for quality control, $C_p(m) = g(m) + \eta$. $g(m)$ is the increasing function of level of quality control m. $\eta \sim N(0, \sigma_\eta^2)$ shows the influence of the external environment factor on quality control cost
F	The penalty that the Platform obtains when the Platform discovers that the Seller provides noncompliant product, $F > 0$
x	Control probability of the Platform
y	Compliance probability of the Seller

Table 2: The payoff matrix without risk attitudes.

Seller	Platform	
	Control x	Not control $1-x$
Compliance y	$(B_s + (1-r)l(n_1) - C_s(n_1), B_p + rl(n_1) - C_p(m))$	$(B_s + (1-r)l(n_1) - C_s(n_1), B_p + rl(n_1) - \beta M_2)$
Not compliance $1-y$	$(B_s + (1-r)l(n_2) - C_s(n_2) - mF - \alpha M_1, B_p + rl(n_2) - C_p(m) + mF)$	$(B_s + (1-r)l(n_2) - C_s(n_2) - \alpha M_1, B_p + rl(n_2) - \beta M_2)$

Assumption 4: risk gain (loss) is related to both the player's own risk attitude and that of the other player because of the interaction. Moreover, the risk loss (gain) is both influenced by Platform's control probability and Seller's compliance probability [7].

Assumption 5: risk attitudes can bring risk gains or loss to decision-makers, but in reality, risk gain and risk loss are often weakened by market irregularities, such as quality fraud behaviours. The product quality supervision of government can enhance the degree of market regulation to make the risk revenue closer to the original risk gain or loss [40].

Table 3 includes the parameters and descriptions for Model II.

In terms of the above assumptions and expected risk revenue functions in Liu and Wang [7], we establish the expected risk revenue functions of the Platform and the Seller as

$$\begin{aligned} R_p(x, y) &= \beta\left[\frac{1}{2}A_p\left(y\sigma_\varepsilon^2 + x\sigma_\eta^2\right) + \frac{1}{2}\mu_1 A_s\left(y\sigma_\varepsilon^2 + x\sigma_\eta^2\right)\right] \\ &= \frac{1}{2}\beta\left(A_p + \mu_1 A_s\right)\left(y\sigma_\varepsilon^2 + x\sigma_\eta^2\right), \end{aligned} \tag{1}$$

where $\mu_1\ (0 \le \mu_1 \le 1)$ is the influence factor of the Seller's risk attitude factor on expected Platform's risk revenue:

$$\begin{aligned} R_s(x, y) &= \alpha\left[\frac{1}{2}A_s\left(y\sigma_\varepsilon^2 + x\sigma_\eta^2\right) + \frac{1}{2}\mu_2 A_p\left(y\sigma_\varepsilon^2 + x\sigma_\eta^2\right)\right] \\ &= \frac{1}{2}\alpha\left(A_s + \mu_2 A_p\right)\left(y\sigma_\varepsilon^2 + x\sigma_\eta^2\right), \end{aligned} \tag{2}$$

where $\mu_2\ (0 \le \mu_2 \le 1)$ is the influence factor of the Platform's risk attitude factor on expected Seller's risk revenue.

$R_p(x, y) > 0$ or $R_s(x, y) > 0$ indicates expected risk loss, while $R_p(x, y) < 0$ or $R_s(x, y) < 0$ indicates expected risk gain. Then, the risk payoff matrix can be determined, as shown in Table 4.

Based on the payoff matrix without risk attitudes (Table 2) and the risk payoff matrix (Table 4), the expected revenue of the Platform choosing to control the product quality of the Seller can be calculated as

$$\begin{aligned} E_1 = {} & B_p - C_p(m) + yrl(n_1) + (1-y)rl(n_2) + (1-y)mF \\ & - \frac{1}{2}\beta\left(A_p + \mu_1 A_s\right)\left(y\sigma_\varepsilon^2 + \sigma_\eta^2\right). \end{aligned} \tag{3}$$

Table 3: Symbols and descriptions of parameters for Model II.

Symbol	Description
A_p	Risk attitude of the Platform
A_s	Risk attitude of the Seller
μ_1	The influence of the Seller's risk attitude on risk revenue of Platform, $0 \leq \mu_1 \leq 1$
μ_2	The influence of the Platform's risk attitude on risk revenue of Seller, $0 \leq \mu_2 \leq 1$
$R_p(x, y)$	The expected risk revenue of Platform
$R_s(x, y)$	The expected risk revenue of Seller

Table 4: The risk payoff matrix.

Seller	Platform	
	Control x	Not control $1-x$
Compliance y	$(-(1/2)\alpha(A_s+\mu_2 A_p)(\sigma_\varepsilon^2+\sigma_\eta^2), -(1/2)\beta(A_p+\mu_1 A_s)(\sigma_\varepsilon^2+\sigma_\eta^2))$	$(-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2, -(1/2)\beta(A_p+\mu_1 A_s)\sigma_\varepsilon^2)$
Not compliance $1-y$	$(-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\eta^2, -(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2)$	$(0, 0)$

The expected revenue of the Platform choosing not control strategy can be calculated as

$$E_2 = B_p - \beta M_2 + yrl(n_1) + (1-y)rl(n_2) - \frac{1}{2}\beta\left(A_p + \mu_1 A_s\right)y\sigma_\varepsilon^2. \tag{4}$$

The average expected revenue of the Seller is

$$E_p = B_p - (1-x)\beta M_2 + yrl(n_1) + (1-y)rl(n_2) - xC_p(m) + x(1-y)mF - \frac{1}{2}\beta\left(A_p + \mu_1 A_s\right)\left(y\sigma_\varepsilon^2 + x\sigma_\eta^2\right). \tag{5}$$

Thus, the replicator dynamic equation of the Seller can be determined as

$$\frac{\mathrm{d}x}{\mathrm{d}t} = x\left(E_1 - E_p\right) = x(1-x)\left[(1-y)mF - C_p(m) + \beta M_2 - \frac{1}{2}\beta\left(A_p + \mu_1 A_s\right)\sigma_\eta^2\right]. \tag{6}$$

Similarly, the replicator dynamic equation of the Seller can be determined as

$$\frac{\mathrm{d}y}{\mathrm{d}t} = y(1-y)\left[(1-r)\Delta l - \Delta C_s + \alpha M_1 + xmF - \frac{1}{2}\alpha\left(A_s + \mu_2 A_p\right)\sigma_\varepsilon^2\right], \tag{7}$$

where $\Delta l = l(n_1) - l(n_2)$, $\Delta C_s = C_s(n_1) - C_s(n_2)$. The evolutionary process can be analysed by the replicator dynamic equations above.

Let $\mathrm{d}y/\mathrm{d}t = 0$ and $\mathrm{d}x/\mathrm{d}t = 0$ at the same time, and we can get five equilibrium points, $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$, and (x^*, y^*). $x^* = -[(1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2]/mF$, $y^* = [mF - C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2]/mF$.

In terms of the literature [41], the Jacobian matrix J of the two-dimensional dynamic system constructed by the two replicator dynamic equations is

$$J = \begin{bmatrix} (1-2x)H & -x(1-x)mF \\ y(1-y)mF & (1-2y)I \end{bmatrix}, \tag{8}$$

where $H = (1-y)mF - C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2$ and $I = (1-r)\Delta l - \Delta C_s + \alpha M_1 + xmF - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2$.

The determinant of Jacobian matrix is

$$\det J = (1-2x)(1-2y)HI + xy(1-x)(1-y)m^2F^2. \tag{9}$$

The trace of Jacobian matrix is

$$\operatorname{tr} J = (1-2x)H + (1-2y)I. \tag{10}$$

Only when $\det J > 0$ and $\operatorname{tr} J < 0$ are satisfied at the same time, the evolutionary stability strategy (ESS) can be obtained at the equilibrium point of the replication dynamic equations. The local equilibrium point (x^*, y^*) cannot be the ESS because $\operatorname{tr} J = 0$ when $x = x^*$, $y = y^*$. Thus, only the four points $(0,0)$, $(0,1)$, $(1,0)$, and $(1,1)$ need to be analysed. According to the criteria of $\det J > 0$ and $\operatorname{tr} J < 0$, five cases should be discussed:

Case 1: $(0,0)$ is the evolutionary stability strategy (ESS) when $-C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2 < -mF$ and $(1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2 < -mF$ are satisfied simultaneously or when $-C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2 < -mF$ and $-mF < (1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2 < 0$ are satisfied simultaneously.

Case 2: $(1,1)$ is the evolutionary stability strategy (ESS) when $-C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2 > 0$ and $(1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2 > 0$ are satisfied simultaneously or when $-C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2 > 0$ and $-mF < (1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2 < 0$ are satisfied simultaneously.

Case 3: $(0,1)$ is the evolutionary stability strategy (ESS) when $-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2<-mF$ and $(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2>0$ are satisfied simultaneously or when $-mF<-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2<0$ and $(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2>0$ are satisfied simultaneously.

Case 4: $(1,0)$ is the evolutionary stability strategy (ESS) when $-mF<-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2<0$ and $(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2<-mF$ are satisfied simultaneously or when $-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2>0$ and $(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2<-mF$ are satisfied simultaneously.

Case 5: there is no evolutionary stability strategy (ESS) when $-mF<-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2<0$ and $-mF<(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2<0$ are satisfied simultaneously.

4. Numerical Analysis

To validate all cases above and investigate the impacts of risk attitudes and government supervision intensities, this study performs numerical evolution and simulation analysis using MATLAB software to simulate the evolutionary game process of online shopping quality control.

4.1. Verification of Evolutionary Stability Strategy Case. The first step of simulating the evolutionary stability strategy cases is to set initial values of game model parameters. Two requirements need to be satisfied while assigning the parameters. The first is the parameter values which should confirm the reality of online shopping quality control in China as properly as possible. The second is the value setting which should provide the conditions to simulate all cases as discussed above. Thus, we consulted 12 experts in the field of electronic commerce and quality management in China. The initial values of parameters in this paper are as follows:

The revenue coefficient of the Platform from total additional revenue r is 0.1. The range of Δl, the total additional revenue difference between high-level quality effort and low-level quality effort of the Seller, is 20–50. The range of ΔC_s, the Seller's cost difference between high-level quality effort and low-level quality effort, is 20–80. The penalty mF that the Platform obtains from the Seller with the level m of quality control is 30. The range of $C_p(m)$, the relevant cost of the Platform for quality control, is 20–60. The set of risk attitude values of the Platform and the Seller A_p, A_s is {−1,0,1}. The influence of the Seller's risk attitude on risk revenue of Platform μ_1 and the influence of the Platform's risk attitude on risk revenue of Seller μ_2 are both 0.5. M_1 and M_2, the government benchmark fines for the Seller and the Platform, are both 50. α and β, the government supervision intensities for the Seller and the Platform, are equal with the range of 0.2–0.8. σ_ε^2 and σ_η^2, the variances of impacts of external environment factors, are 50 and 30, respectively. We assume four combinations of initial strategy probabilities, $x=0.2$ and $y=0.2$, $x=0.4$ and $y=0.4$, $x=0.6$ and $y=0.6$, and $x=0.8$ and $y=0.8$. The value setting of the simulations is shown in Table 5. Figures 1–5 show the evolutionary simulation results of five cases.

As shown in Figure 1, the dynamic system of behaviour choices has an evolutionary stable point $(0,0)$. That means the Platform will not control the product quality and the Seller will not provide the compliant products as time going on while satisfying the following conditions at the same time: ① the sum of mF (the Platform's penalty for the Seller) and βM_2 (the government's penalty for the Platform) is smaller than the sum of $C_p(m)$ (the controlling cost of the Platform) and $(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2$ (the Platform's risk loss with the strategy combination of (Control, Not compliance)); ② the sum of $(1-r)\Delta l$ (the difference of the Seller's gain from the total additional revenue) and αM_1 (the government's penalty for the Seller) is smaller than the sum of ΔC_s (the difference of the Seller's cost) and $(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2$ (the Seller's risk loss with the strategy combination of (Not control, Compliance)). In particular, Figure 1(a) shows that y (compliance probability of the Seller) evolves to 0 faster than x (control probability of the Platform) when $-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2<-mF$ and $(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2<-mF$, and Figure 1(b) shows that y evolves to 0 more slowly than x when $-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2<-mF$ and $-mF<(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2<0$.

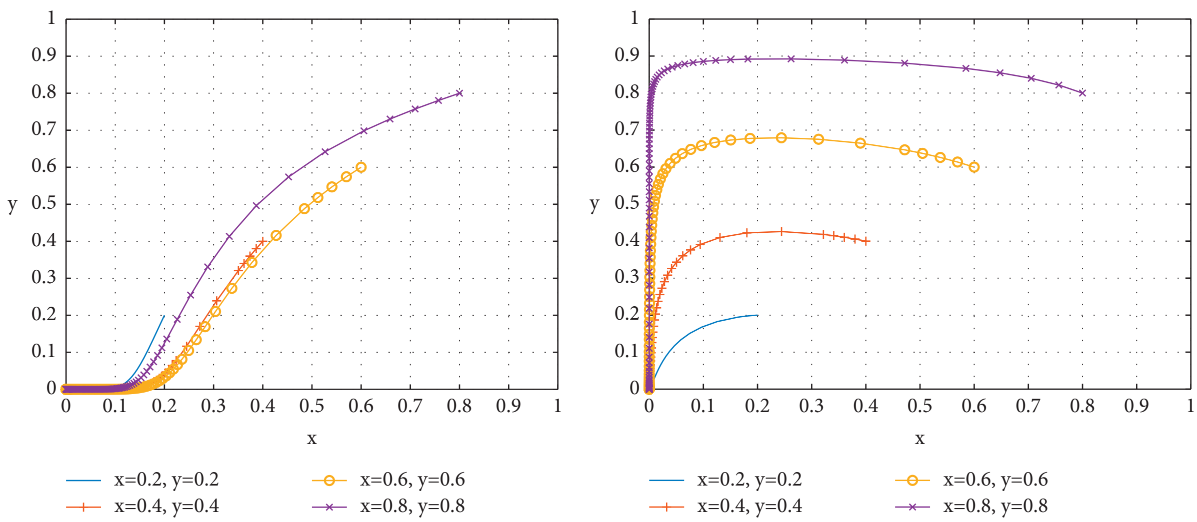
As shown in Figure 2, the dynamic system of behaviour choices has an evolution stable point $(1,1)$. That means the Platform will control the product quality and the Seller will provide the compliant products as time going on while satisfying the following conditions at the same time: ① the sum of βM_2 (the government's penalty for the Platform) and $-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2$ (the Platform's risk gain with the strategy combination of (Control, Not compliance)) is bigger than $C_p(m)$ (the controlling cost of the Platform); ② the sum of mF (the Platform's penalty for the Seller), $(1-r)\Delta l$ (the difference of the Seller's gain from the total additional revenue), αM_1 (the government's penalty for the Seller), and $-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2$ (the Seller's risk gain with the strategy combination of (Not control, Compliance)) is bigger than ΔC_s (the difference of the Seller's cost). In particular, Figure 2(a) shows that y (compliance probability of the Seller) evolves to 1 faster than x (control probability of the Platform) when $-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2>0$ and $(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2>0$, and Figure 2(b) shows that y and x evolve to 1 almost simultaneously when $-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2>0$ and $-mF<(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2<0$.

As shown in Figure 3, the dynamic system of behaviour choices has an evolution stable point $(0,1)$. That means the Platform will not control the product quality and the Seller will provide the compliant products as time going on while satisfying the following conditions at the same time: ① the sum of βM_2 (the government's penalty for the Platform) and $-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2$ (the Platform's risk gain with the strategy combination of (Control, Not compliance)) is smaller than $C_p(m)$ (the controlling cost of the Platform); ② the sum of $(1-r)\Delta l$ (the difference of the Seller's gain from

Table 5: Simulated values of parameters in the case of evolutionary stabilization strategy.

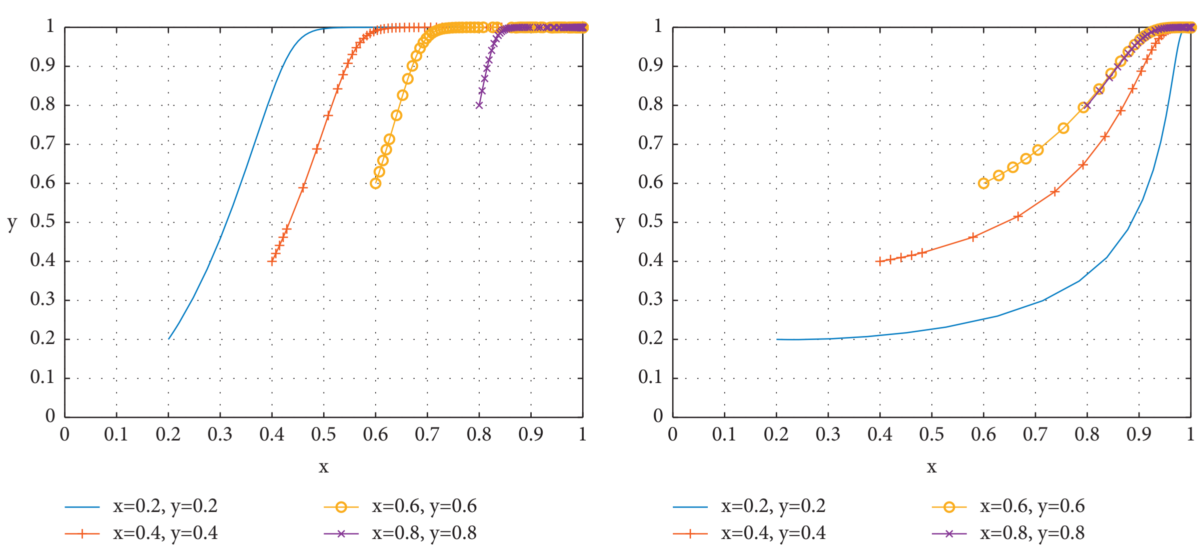
Case	Figure	Evolutionary stability conditions	r	Δl	ΔC_s	mF	A_s	A_p	μ_1	μ_2	σ_ε^2	σ_η^2	$C_p(m)$	α	M_1	β	M_2
Case 1	1(a)	$K < -mF$ and $L < -mF$	0.1	20	80	30	0	0	0.5	0.5	50	30	60	0.5	50	0.5	50
	1(b)	$K < -mF$ and $-mF < L < 0$	0.1	20	50	30	0	0	0.5	0.5	50	30	60	0.5	50	0.5	50
Case 2	2(a)	$K > 0$ and $L > 0$	0.1	50	20	30	0	0	0.5	0.5	50	30	20	0.5	50	0.5	50
	2(b)	$K > 0$ and $-mF < L < 0$	0.1	20	50	30	0	0	0.5	0.5	50	30	20	0.5	50	0.5	50
Case 3	3(a)	$K < -mF$ and $L > 0$	0.1	50	20	30	0	0	0.5	0.5	50	30	60	0.5	50	0.5	50
	3(b)	$-mF < K < 0$ and $L > 0$	0.1	50	20	30	0	0	0.5	0.5	50	30	40	0.5	50	0.5	50
Case 4	4(a)	$-mF < K < 0$ and $L < -mF$	0.1	20	80	30	0	0	0.5	0.5	50	30	40	0.5	50	0.5	50
	4(b)	$K > 0$ and $L < -mF$	0.1	20	80	30	0	0	0.5	0.5	50	30	20	0.5	50	0.5	50
Case 5	5	$-mF < K < 0$ and $-mF < L < 0$	0.1	20	50	30	0	0	0.5	0.5	50	30	40	0.5	50	0.5	50

Notes: $K = -C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2$, $L = (1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2$.



(a) (b)

Figure 1: Simulation results of Case 1.



(a) (b)

Figure 2: Simulation results of Case 2.

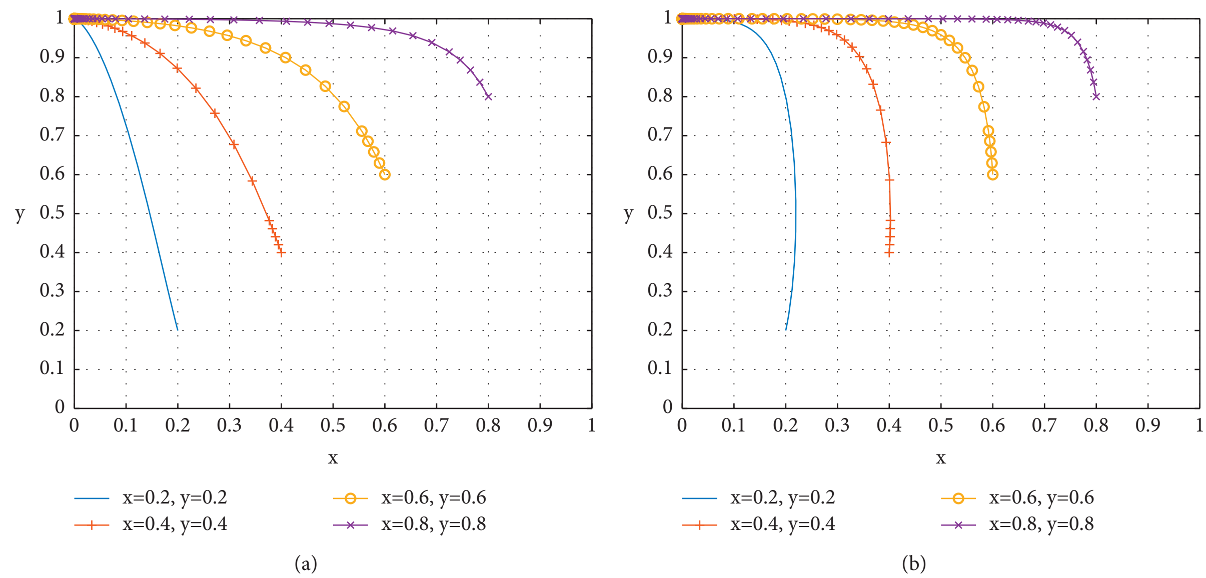


FIGURE 3: Simulation results of Case 3.

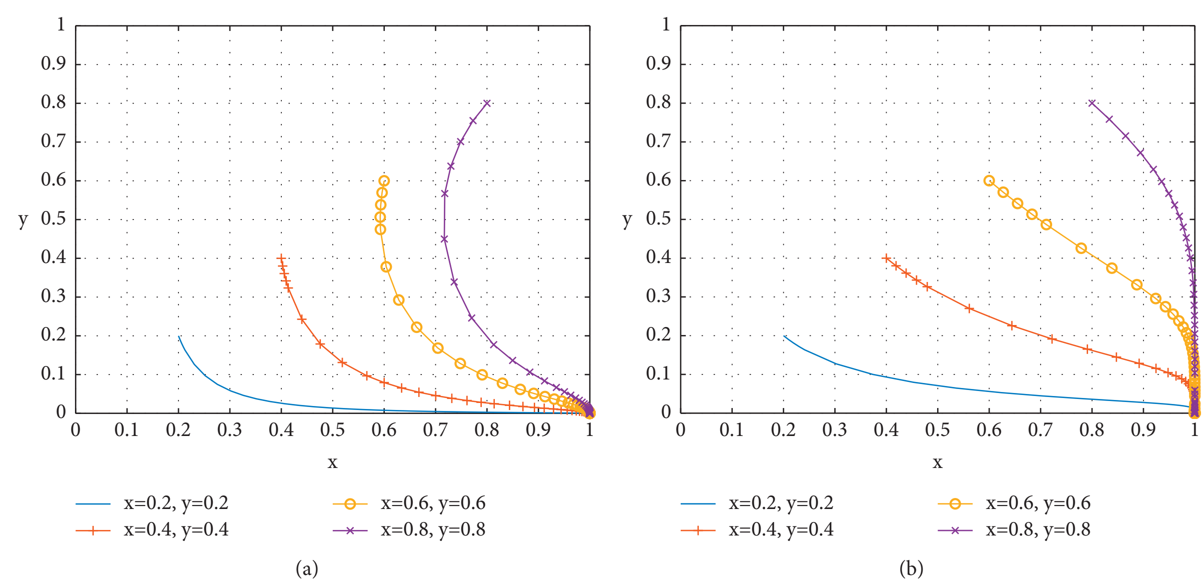


FIGURE 4: Simulation results of Case 4.

the total additional revenue), αM_1 (the government's penalty for the Seller), and $-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2$ (the Seller's risk gain with the strategy combination of (Not control, Compliance)) is bigger than ΔC_s (the difference of the Seller's cost). In particular, compared with y (compliance probability of the Seller) in Figure 3(a), y in Figure 3(b) evolves faster to 1. That means, when $-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2<0$ and $(1-r)\Delta l-\Delta C_s+\alpha M_1-(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2>0$, compliance probability of the Seller will evolve to 1 relatively faster if $-mF<-C_p(m)+\beta M_2-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2$.

As shown in Figure 4, the dynamic system of behaviour choices has an evolution stable point $(1,0)$. That means the Platform will control the product quality and the Seller will not provide the compliant products as time going on while satisfying the following conditions at the same time: ① the sum of mF (the Platform's penalty for the Seller), βM_2 (the government's penalty for the Platform), and $-(1/2)\beta(A_p+\mu_1 A_s)\sigma_\eta^2$ (the Platform's risk gain with the strategy combination of (Control, Not compliance)) is bigger than $C_p(m)$ (the controlling cost of the Platform); ② the sum of $(1-r)\Delta l$ (the difference of the Seller's gain from the total additional revenue), αM_1 (the government's penalty for the Seller), and mF (the Platform's penalty for the Seller) is smaller than the sum of ΔC_s (the difference of the Seller's cost) and $(1/2)\alpha(A_s+\mu_2 A_p)\sigma_\varepsilon^2$ (the Seller's risk loss with the strategy combination of (Not control, Compliance)). In particular, Figure 4(a) shows that y (compliance probability

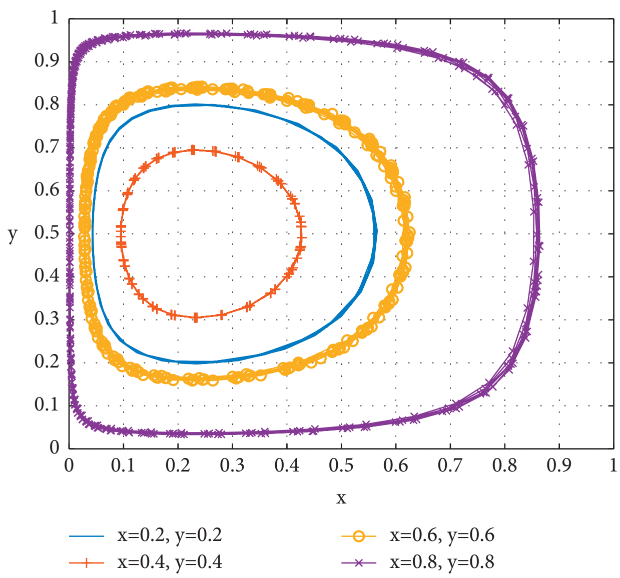


FIGURE 5: Simulation result of Case 5.

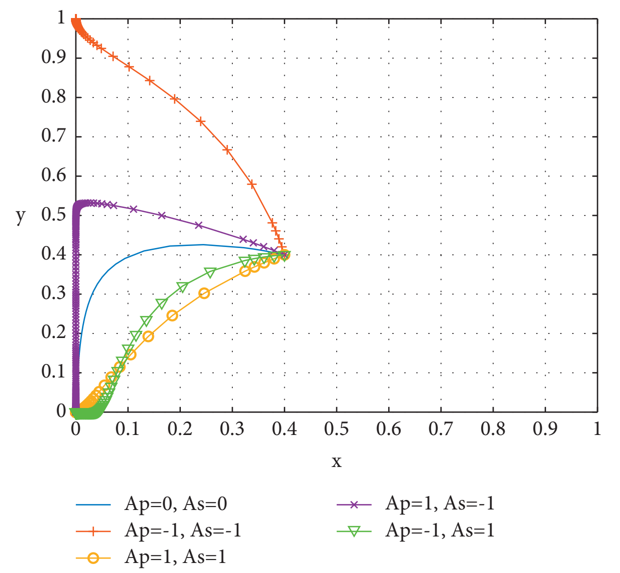


FIGURE 6: Evolution results with the change of risk attitudes by the initial values in Case 1.

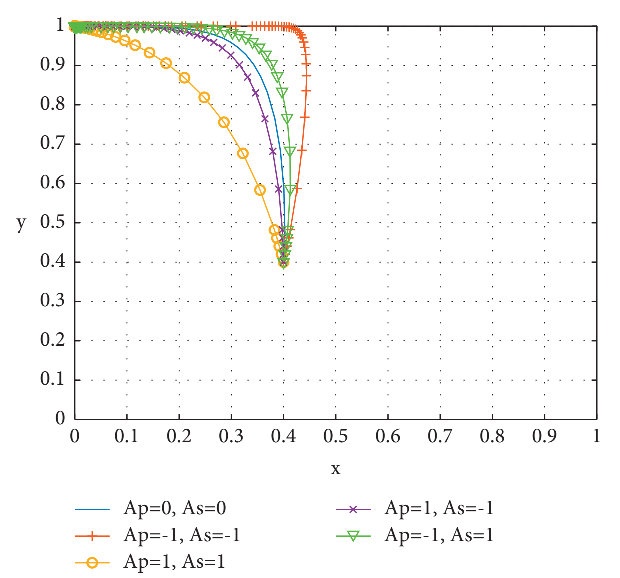


FIGURE 7: Evolution results with the change of risk attitudes by the initial values in Case 3.

of the Seller) evolves to the stable state earlier than x (control probability of the Platform) when $-mF < -C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2 < 0$ and $(1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2 < -mF$, and Figure 4(b) shows that y evolves to the stable state after x when $-C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2 > 0$ and $(1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2 < -mF$.

As shown in Figure 5, the dynamic system of behaviour choices has no evolutionary stable point. That means the Platform and the Seller are all in a cyclical state with no stable evolution strategy as time going on while satisfying the following conditions at the same time: ① $-mF < -C_p(m) + \beta M_2 - (1/2)\beta(A_p + \mu_1 A_s)\sigma_\eta^2 < 0$; ② $-mF < (1-r)\Delta l - \Delta C_s + \alpha M_1 - (1/2)\alpha(A_s + \mu_2 A_p)\sigma_\varepsilon^2 < 0$.

4.2. Simulation Analysis of the Influence of Key Parameter Variables. In this section, the impacts of risk attitude and government supervision intensity on the evolutionary results are discussed using the simulation analysis. To investigate the impacts in different conditions, we consider the parameter value settings of three cases (Case 1, Case 3, and Case 4) as the initial values of simulation and then treat the risk attitude combinations and government supervision intensities as sets of variables. First, we set initial probabilities $x = 0.4$ and $y = 0.4$, assume the supervision intensities $\alpha = 0.5$ and $\beta = 0.5$, and simulate the evolutionary results with five risk attitude combinations in the three cases. The five risk attitude combinations are as follows: ① $A_p = 0, A_s = 0$, ② $A_p = -1, A_s = -1$, ③ $A_p = 1, A_s = 1$, ④ $A_p = 1, A_s = -1$, and ⑤ $A_p = -1, A_s = 1$. The simulation results are shown in Figures 6–8. Second, we test the impacts of supervision intensity of the government under each risk attitude combination by simulating the evolutionary track with the change of α and β. The five setting values of intensity are as follows: ① $\alpha = 0.2, \beta = 0.2$, ② $\alpha = 0.35, \beta = 0.35$, ③ $\alpha = 0.5, \beta = 0.5$, ④ $\alpha = 0.65, \beta = 0.65$, and ⑤ $\alpha = 0.8$, $\beta = 0.8$, representing the intensities from low to high. The simulation results of the impacts of supervision intensity are shown in Figures 9(a)–9(e), 10(a)–10(e), and 11(a)–11(e).

Figure 6 shows that the dynamic system of the members' strategy choices evolves from the ESS $(0, 0)$ to the ESS $(0, 1)$ when the risk attitude combinations are set as $A_p = -1, A_s = -1$ with the initial values of other parameters assigned as Figure 1. That means risk-seeking attitudes of the Platform and the Seller make contributions to promoting the evolution of online shopping quality control process in a positive direction for Case 1.

Figure 9 shows the results of simulation when risk attitudes and supervision intensities are considered as variables with the values of other parameters assigned as

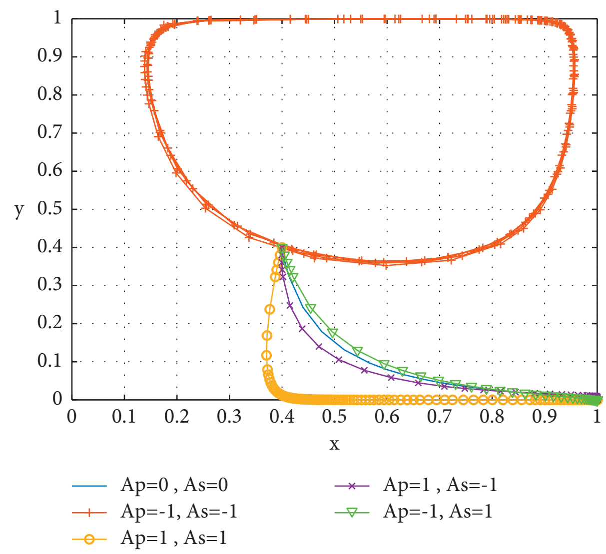


Figure 8: Evolution results with the change of risk attitudes by the initial values in Case 4.

Figure 1(b). Figure 9(a) shows that the dynamic system of the strategy choices of members evolves from the ESS $(0, 0)$ to the ESS $(0, 1)$ when both α and β are no less than 0.65 with $A_p = 0, A_s = 0$. Similarly, Figure 9(b) shows that the dynamic system of the strategy choices of members evolves from the ESS $(0, 0)$ to the ESS $(0, 1)$ when both α and β are no less than 0.5 with $A_p = -1, A_s = -1$. Figure 9(d) shows that the dynamic system of the strategy choices of members evolves from the ESS $(0, 0)$ to the ESS $(0, 1)$ when both α and β are no less than 0.65 with $A_p = 1, A_s = -1$. These results indicate that under the condition satisfying Figure 1(b), higher intensities of the government supervision make contributions to promoting the evolution of online shopping quality control process in a positive direction when one of the following three situations occurs: ① both the Platform and the Seller are risk-neutral, ② both the Platform and the Seller are risk-seeking, and ③ the Platform is risk-averse and the Seller is risk-seeking. In contrast, the intensities of the government supervision have almost no effect on the outcome of the evolutionary process when $A_p = 1, A_s = 1$as shown in Figure 9(c). Moreover, with the risk attitude combination of the $A_p = -1, A_s = 1$, the dynamic system is in a cyclical state with no stable evolutionary strategy as time going on when higher intensities are no less than 0.65 as shown in Figure 9(e).

Figure 7 shows that the evolution results of dynamic system of the members' strategy choices have no obvious change with various risk attitude combinations. That means, for Case 3, risk attitudes of the Platform and the Seller have no significant impact on the evolution directions of members' behaviour strategies.

Figure 10 shows the results of simulation when risk attitudes and supervision intensities are considered as variables with the values of other parameters assigned as Figure 3(b). Figure 10(b) shows that the dynamic system of the strategy choices of members evolves from the ESS $(0, 1)$ to the ESS $(1, 1)$ when both α and β are no less than 0.65 with $A_p = -1, A_s = -1$. Similarly, Figure 10(e) shows that the dynamic system of the strategy choices of members evolves from the ESS $(0, 1)$ to the ESS $(1, 1)$ when both α and β are no less than 0.8 with $A_p = -1, A_s = 1$. These mean that under the condition satisfying Figure 3(b), higher intensities of the government supervision make contribution to promoting the evolution of online shopping quality control process in a positive direction when one of the following two situations occurs: ① both the Platform and the Seller are risk-seeking; ② the Platform is risk-seeking and the Seller is risk-averse. In contrast, the intensities of the government supervision have almost no effect on the results of the evolutionary process when $A_p = 1, A_s = 1$ or $A_p = 1, A_s = -1$ as shown in Figures 10(c) and 10(d).

Figure 8 shows that the dynamic system of the members' strategy choices has no evolutionary stability strategy (ESS) when $A_p = -1, A_s = -1$ with the values of other parameters assigned as Figure 4(a). In addition, other risk attitude combinations do not change the evolutionary stability strategy (ESS) $(1, 0)$ for Case 4.

Figure 11 shows the results of simulation when risk attitudes and supervision intensities are considered as variables with the values of other parameters assigned as Figure 4(a). Figure 11(a) shows that the dynamic system of the strategy choices of members evolves from the ESS $(1, 0))$ to the ESS $(1, 1)$ when both α and β are no less than 0.8 with $A_p = 0, A_s = 0$. Similarly, Figure 11(b) shows that the dynamic system of the strategy choices of members evolves from the ESS $(1, 0)$ to the ESS $(1, 1)$ when both α and β are no less than 0.65 with $A_p = -1, A_s = -1$. Figure 11(c) shows that the dynamic system of the strategy choices of members evolves from the ESS $(1, 0)$ to the ESS $(0, 0)$ when both α and β are no more than 0.35 with $A_p = 1, A_s = 1$. These results indicate that under the condition satisfying Figure 4(a), higher intensities of the government supervision make

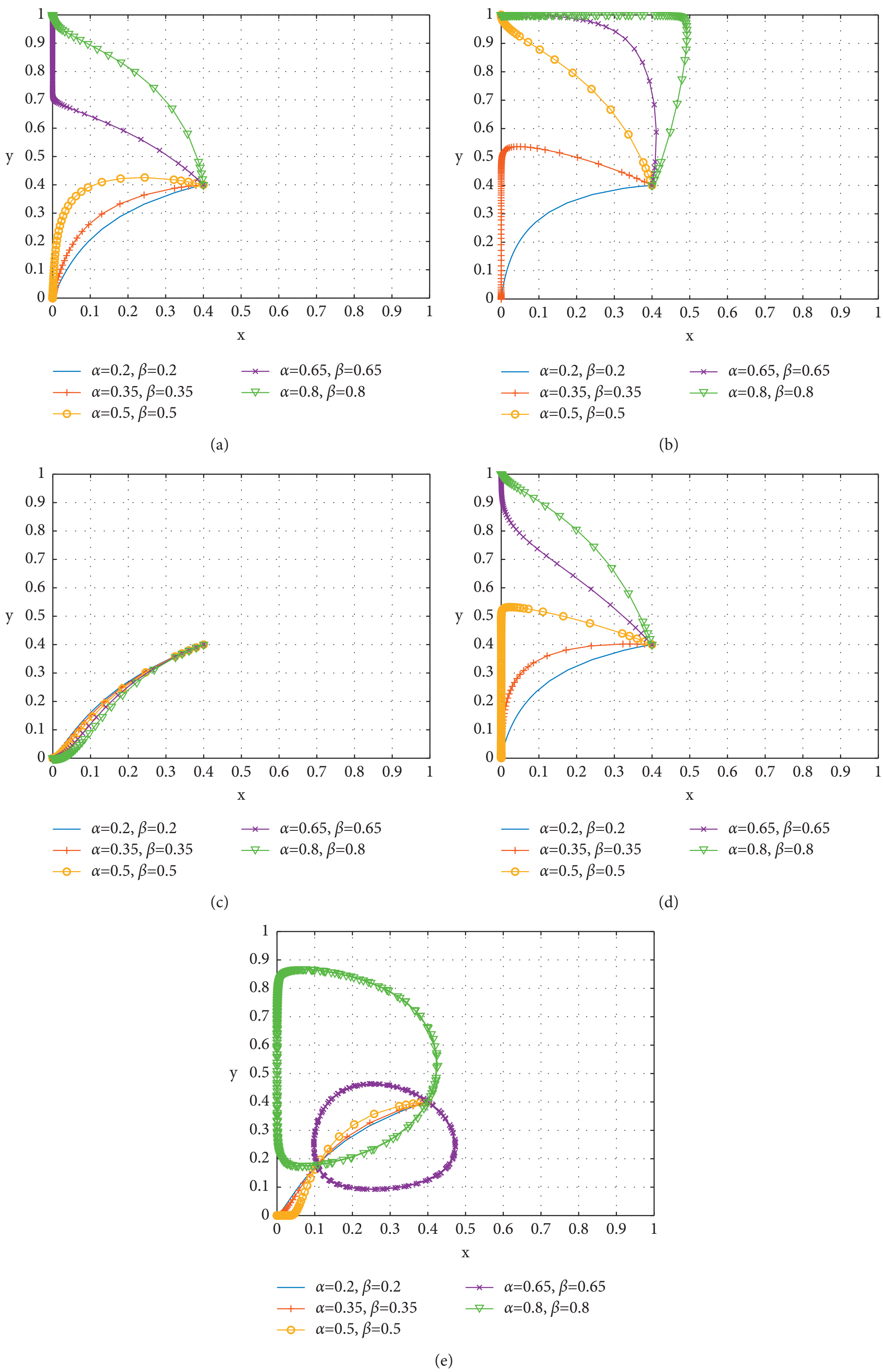


Figure 9: Evolution results with the change of α and β by the initial values in Case 1. (a) $A_p = 0, A_s = 0$. (b) $A_p = -1, A_s = -1$. (c) $A_p = 1, A_s = 1$. (d) $A_p = 1, A_s = -1$. (e) $A_p = -1, A_s = 1$.

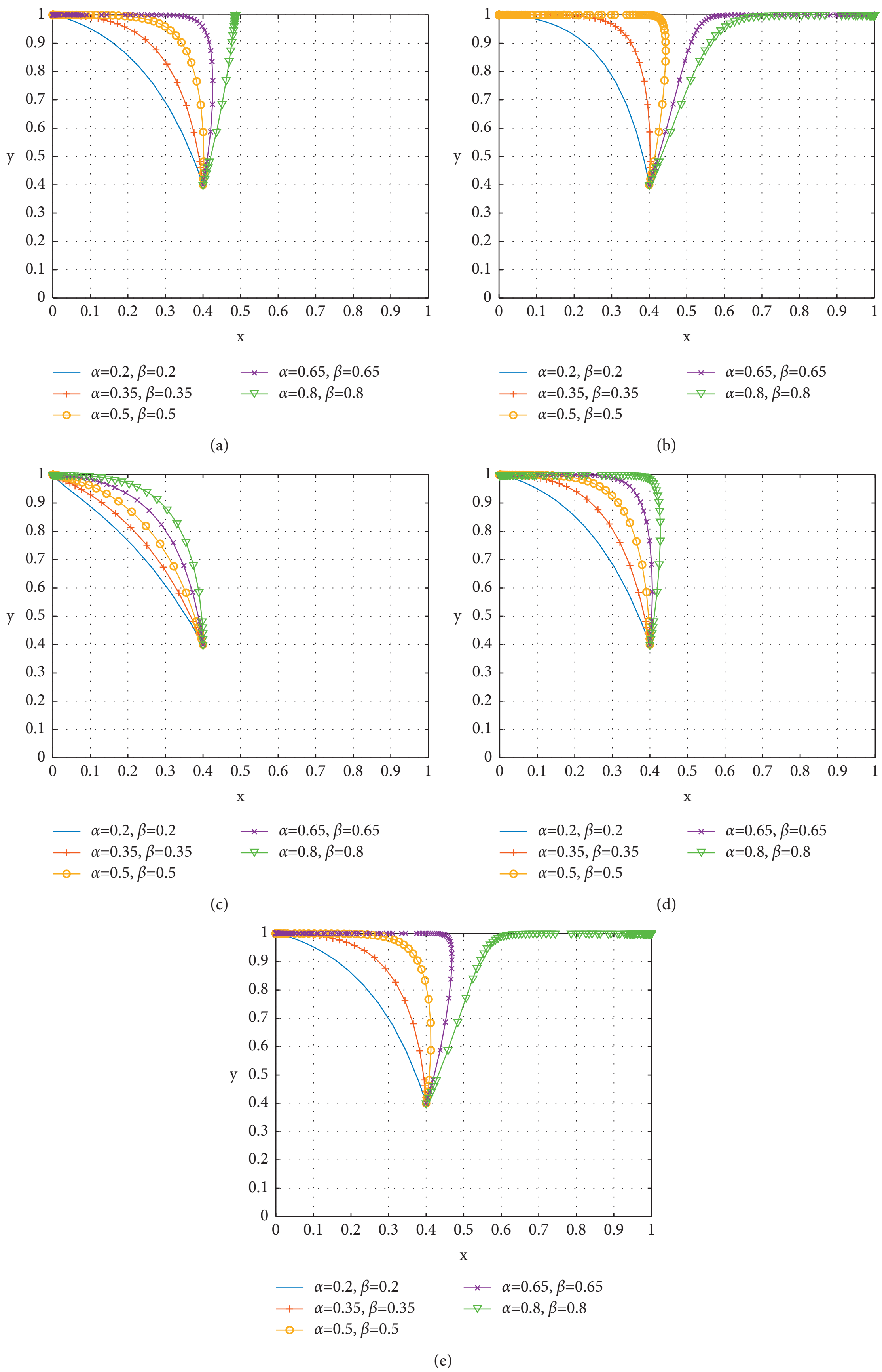


Figure 10: Evolution results with the change of α and β by the initial values in Case 3. (a) $A_p = 0, A_s = 0$. (b) $A_p = -1, A_s = -1$. (c) $A_p = 1, A_s = 1$. (d) $A_p = 1, A_s = -1$. (e) $A_p = -1, A_s = 1$.

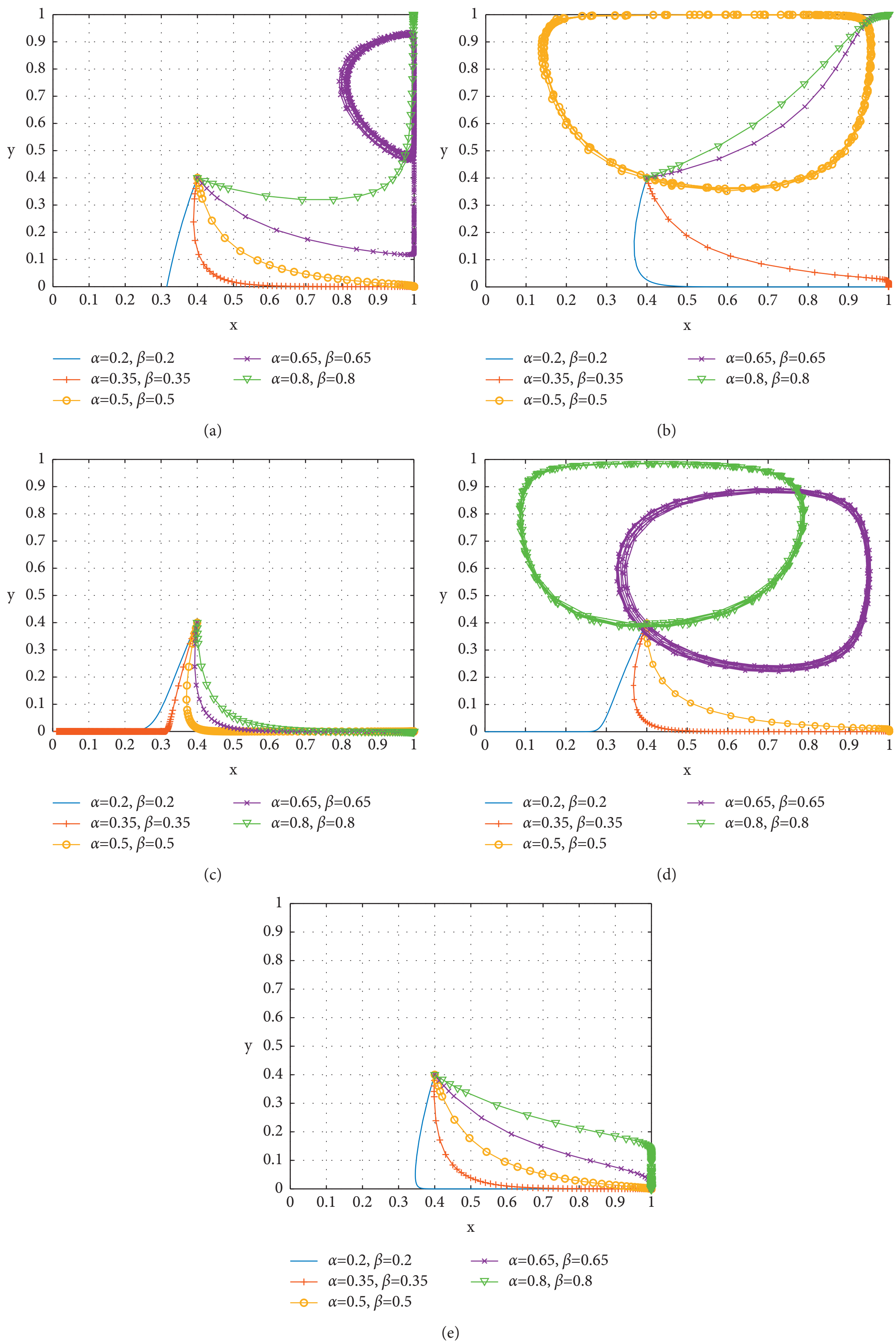


Figure 11: Evolution results with the change of α and β by the initial values in Case 4. (a) $A_p = 0, A_s = 0$. (b) $A_p = -1, A_s = -1$. (c) $A_p = 1, A_s = 1$. (d) $A_p = 1, A_s = -1$. (e) $A_p = -1, A_s = 1$.

contribution to promoting the evolution of online shopping quality control process in a positive direction when the Platform and the Seller have the same risk attitude, regardless of risk-neutral, risk-seeking, or risk-aversion. In contrast, the intensities of the government supervision have almost no effect on the outcome of the evolutionary process when $A_p = -1, A_s = 1$ as shown in Figure 11(e). Moreover, with the risk attitude combination of the $A_p = 1, A_s = -1$, the dynamic system is in a cyclical state with no stable evolutionary strategy as time going on when higher intensities are no less than 0.65 as shown in Figure 11(c). It is worth noting that when the supervision intensity takes some certain values ($\alpha = \beta = 0.65$ in Figure 11(a) or $\alpha = \beta = 0.5$ in Figure 11(b)), the dynamic system does not have an evolutionary stable strategy but is in cyclical fluctuations. That indicates that some medium supervision intensities may cause the participants' strategy evolution to be unstable when both the Platform's and the Seller's risk attitudes are risk-neutral or risk-seeking.

5. Conclusions and Discussion

In this paper, we establish the evolutionary game model of online shopping quality control between the Platform and the Seller with the consideration of risk attitudes and the government supervision by using simulation analysis. Section 5.1 will clarify the major conclusions. The implications in view of the academic areas and practical areas will be discussed in Section 5.2. Section 5.3 provides the limitations and future research of this paper.

5.1. Major Conclusions. In terms of the analysis in Sections 3 and 4, three major conclusions can be addressed as follows:

(1) The factors affecting the evolutionary stable strategy of the online shopping quality game include: the Platform's cost of quality control, the intensities of government supervision, the government's fine for the members, the control level of the Platform and the fines imposed on sellers, the difference of extra revenue of the Seller between two different choices, the cost difference of the Seller between two different choices, as well as the Platform's risk revenue with the strategy combination of (Control, Not compliance) and the Seller's risk revenue with the strategy combination of (Not control, Compliance). As for the Platform, when the government's penalty for the Platform and the Platform's risk revenue with the strategy combination of (Control, Not compliance) are big enough compared with the control cost, controlling the quality of the Seller is the better strategic choice of the Platform. As for the Seller, providing the compliant products is the better strategic choice of the Seller when the difference of extra revenue of the Seller with two different choices and the government's penalty for the Seller and the Seller's risk revenue with the strategy combination of (Not control, Compliance) are big enough compared with the cost difference of the Seller between the two different choices.

(2) The double risk-seeking attitudes can promote the positive evolution of the dynamic system of the members' strategy choices from the ESS $(0, 0)$ to the ESS $(0, 1)$ in some cases. That means, in some special cases, the risk-seeking members will gradually tend to decide to choose self-disciplined behavioural strategies. In other more cases, no matter what kind of members cannot evolve in a positive direction on their own. In contrast, the double risk-seeking attitudes can transform the evolutionary result from ESS $(1, 0)$ into the cyclical fluctuations with the medium government supervision intensities ($\alpha = \beta = 0.5$).

(3) The government quality supervision has different effects on quality assurance and improvement in the various case. On the one hand, strengthening the intensity of government supervision can promote the benign transformation of evolutionary game results in some cases. The high government supervision intensity can transform the evolutionary stable strategy from $(0, 0)$ into $(0, 1)$ when risk attitude combination of the Platform and the Seller is (risk-neutral, risk-neutral) or (risk-seeking, risk-seeking) or (risk-aversion, risk-seeking). The high government supervision intensity can transform the evolutionary stable strategy from $(0, 1)$ into $(1, 1)$ when risk attitude combination of the Platform and the Seller is (risk-seeking, risk-seeking) or (risk-seeking, risk-aversion). The high government supervision intensity can transform the evolutionary stable strategy from $(1, 0)$ into $(1, 1)$ when risk attitude combination of the Platform and the Seller is (risk-seeking, risk-seeking) or (risk-neutral, risk-neutral). On the other hand, the changes of the government supervision intensities may not help and may even cause cyclical fluctuations in the evolutionary system in some cases. The high intensities of government supervision ($\alpha, \beta \geq 0.65$) can transform the evolutionary result from ESS $(0, 0)$ into the cyclical fluctuations when the Platform is risk-seeking and the Seller is risk-averse. Moreover, the changes of the supervision intensities may transform the evolutionary result from ESS $(1, 0)$ into the cyclical fluctuations when the Seller's risk attitude is risk-seeking or risk-neutral.

5.2. Implications. In this study, we establish and analyse the evolutionary game model of online shopping quality control to discuss the influence of government supervision intensity on players' behavioural decisions in different risk attitudes cases from the perspective of dynamic evolution. The present study mainly blocks up the current research study gaps from two fields: (1) many previous studies on behavioural decision of online shopping only focus on one stakeholder's risk attitude [38], which ignores the risk attitude interaction of participants. In this paper, we investigate the effects of combinations of risk attitudes on the changes of members' evolutionary stable strategies using simulation analysis. The findings are beneficial for researchers understanding the roles of entities risk attitudes in the overall body of knowledge of online shopping quality control. (2) The dynamics of quality control behaviours of members with different risk attitudes under government supervision is a complex topic. The heterogeneous impacts of government quality supervision are not fully discussed under different circumstances with varied risk attitude combinations of participants in existing theoretical research studies [2, 17, 19, 40, 42]. This study discusses the roles of government supervision intensity on quality control known as a critical symbol of online shopping market sustainability. The different effects of government supervision on the quality control are analysed with various combinations of risk attitudes. The conclusions on the complex impact of the government supervision intensity enrich the research studies of government's supervision theory.

This study also brings some implications for the practical areas. (1) As for the Platform, the decrease of the quality control cost is conducive to increasing the probability of controlling the Seller. The Platform can use the following two methods to promote the Seller to choose to provide high-quality products: ① reducing the proportion of rent collected from sellers, and ② increasing sellers' fraud costs by establishing and strengthening the reputation mechanism and after-sales service rules. (2) As for the Seller, reducing the cost of high-quality products by optimizing the supply chain and other methods will help sellers choose to provide consumers with high-quality products. (3) When the Platform and the Sellers are unwilling to make efforts for quality assurance, the risk-seeking Platform should cooperate with the risk-seeking Seller to make the Seller gradually choose to sell compliant products. (4) The government plays an indispensable role in the quality control of online shopping. The results of this study show that increasing the benchmark fines appropriately can help the quality assurance of the online shopping supply chain. Moreover, the influences of the intensity of government supervision are highly uncertain and complex. It can be inferred from the simulation analysis that when members are all risk-seeking, strengthening government supervision will help promote the transition of members' behavioural choices in a benign direction. It is worth noting that government strengthening quality supervision is not always good for improving product quality. The findings also show that the changes of the supervision intensities may transform behavioural evolutions of the participants into the cyclical fluctuations in some special cases. Based on this, the government should supervise online shopping on the principle of tolerance and prudence. On the one hand, the government should give sufficient space for online shopping to fully stimulate market vitality. On the other hand, the government should appropriately supervise to ensure the interests of participants and promote the high-quality development of the online shopping market.

5.3. Limitation and Future Research. Firstly, a single platform and single seller are considered in this study. In reality, however, there are many platforms and sellers in the online market. In addition, the customer is not involved in this study. Future research studies could be extended by discussing the interactive behaviours of network in the online shopping market.

Secondly, although this study uses the expert consultation method to determine the parameter values of the evolutionary game model simulation, it still cannot perfectly reflect the reality. Future research should try to overcome the difficulty of determining proper parameter values to make the results more helpful to guide the online shopping practice.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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