Journal of Positive School Psychology http://journalppw.com
2022, Vol. 6, No. 9, 522-541

Evolution Of Credit Risk In Cross-Border E-Commerce: Based On The Evolutionary Game Model Between Third-Party Service Providers And Regulators

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Abstract: In the global epidemic environment, cross-border e-commerce is developing rapidly, but the problem of credit risk has become a "pain point" hindering the healthy development of cross-border e-commerce. This study aims to examine the third-party service providers and cross-border e-commerce regulators, which are the primary concerns of consumers. The formation mechanism of the credit risk of cross-border e-commerce was revealed by establishing a credit risk evolutionary game model and a dynamic deduction for both groups. The research found that third-party service providers and regulators influence the credit risk of cross-border e-commerce. Third-party service providers of cross-border e-commerce will gradually evolve into a trustworthy behavior strategy with an increase in operating income or cost. Regulations will pay more attention to regulatory behavior strategies with increasing regulatory operating income or cost. In conclusion, this study suggests that regulators should focus on supervising third-party service providers to increase their trustworthy revenue and improve their service levels. This is of great practical significance for presenting a good credit level in cross-border e-commerce and promoting the healthy development of cross-border e-commerce transactions.

Keywords: Cross-border e-commerce; Credit risk; Evolutionary game model; Third-party service providers; Regulators

1. Introduction

According to the Ministry of Commerce of the People's Republic of China, cross-border e-commerce has increased nearly tenfold in the past five years, with more than 1500 foreign trade comprehensive service enterprises and more than 1900 overseas warehouses. New forms of cross-border e-commerce are developing rapidly [1]. In October 2021, the 7th China (Lianyungang) International Logistics Expo released the "China and Global Cross-border E-commerce Development Report (2021)". According to the report, cross-border e-

commerce related to the “home economy” ushered in spring owing to the impact of COVID-19. Consumers are forced to switch from offline to online shopping, and the consumption potential is constantly tapped and released. Consumers of different ages have improved their proportion of online consumption, and the global average online shopping market has increased by 47% [2]. The development of cross-border e-commerce has created enormous opportunities for the global economy, providing a new growth impetus and leading to a new consumption trend.

Although the development of e-commerce has brought convenience to consumers and saved shopping time and energy, e-commerce also has many risks and deficiencies [3]. In 2020, a refund (28.26%), commodity quality (9.95%), and delivery (9.83%) were still the most popular credit complaints among consumers, according to Diansubao (a well-known online consumption dispute mediation platform). Moreover, consumers have been repeatedly complained about cross-border e-commerce in terms of logistics, payment security, and commodity quality, which directly affects consumers' online shopping experience [4]. Currently, China’s cross-border e-commerce is in the early stage of development, and buyers' scale depends on sellers' size and product quality. If there are credit problems related to product quality in a transaction, consumers' willingness to repurchase will be directly reduced, and sellers' reputations will be damaged [5]. Credit risk has become a "pain point" that hinders the healthy development of cross-border e-commerce.

Cross-border e-commerce refers to a new trading mode in which both parties of transactions in different countries or regions reach commodity or service transactions, complete payment settlement, and logistics distribution through e-commerce platforms [6]. Cross-border e-commerce relations are partnerships between e-commerce enterprises that share information, risks, and benefits within a certain period [7]. Whether an e-commerce enterprise deals with good faith affects consumers’ trust and credit [8]. Therefore, effective cross-border cooperation is closely related to "trust" among stakeholders [9]. As trust refers to actively recognizing the relevant attributes of partners, it can help alleviate the occurrence of uncertainties and risks, thereby promoting cooperation [10]. Therefore, the credit risk of cross-border e-commerce referred to in this study is the uncertainty of credit status in cross-border e-commerce activities or virtual markets [11]. How does this uncertainty in credit status occur, and how can it be avoided? This study focuses on cross-border e-commerce participants with the most complaints and concerns from consumers, namely cross-border e-commerce third-party service providers (cross-border e-commerce platforms, logistics enterprises, cross-border payments, etc.) and regulators (government, customs, international organizations, etc.). This study uses the evolutionary game method to reveal, explain, supplement and expand the research field on the credit risk of

cross-border e-commerce.

2.Previous Research

2.1. Research on the Credit Risk Status of Cross-border E-commerce

In the existing literature, scholars have studied the status quo and impact of credit problems of cross-border e-commerce from different perspectives and concerns. Combined with the actual situation in China, China's cross-border logistics have credit problems such as high cost, long cycle, difficult after-sales service, and inability to track the entire process [12]. The security and convenience of third-party payments in cross-border e-commerce are also crucial to credit factors for consumers [13]. Credit risk factors affecting consumers' willingness to use cross-border logistics services can be more accurately identified through investigation, and perfect cross-border logistics services can promote cross-border e-commerce activities [14]. According to a survey, Korean consumers believe that service quality significantly affects consumers' international purchase intentions [15].

In many cases, there is asymmetry in commodity information. Consumers can only learn more about the product from the information provided by platform merchants, which may lead to differences between the actual product and its description. In addition, platform merchants may use other professional logistics companies to deliver goods, which brings significant risks to the after-sale of goods [16]. In short, the credit problems of cross-border e-commerce, such as product quality, logistics services, payment security, and after-sales service, have significantly affected consumers' perception of credit risk. Credit problems have become a critical factor restricting the development of cross-border e-commerce.

2.2. Related Research Based on the Evolutionary Game Method

Online credit risk problems have a negative impact on online trading. Revealing the formation mechanism of online credit risk is one solution to this problem. From the research of relevant scholars, evolutionary game theory has strong explanatory power for the behavioral choices and evolutionary characteristics of online traders and regulators [17]. From the participants' perspective in adopting cross-border e-commerce, there are two main groups, consumers and brand owners. Through earlier analysis of the evolutionary game model, it was found that the core factors adopted by the participants in cross-border e-commerce transactions were initial input cost, risk-taking ability, fair distribution of excess benefits, and other elements. Therefore, regulatory authorities should establish a restraint mechanism to encourage cross-border e-commerce evolve toward mutual benefits [18]. There are also participants in cross-border e-commerce and logistics enterprises, in both cooperation and competition. Modeling them with the theory of evolutionary games needs to be improved and adjusted through multiple games to

reveal the evolutionary characteristics of their different behavior choice strategies [19]. In the development process of the cross-border e-commerce industry, combined with the evolutionary game and system dynamics, the behavioral selection strategy of government and enterprises can be changed from the aspects of government subsidies, tax incentives, government regulation, and infrastructure construction, which provides theoretical guidance for the government to formulate a management strategy for the cross-border e-commerce industry [20]. The evolutionary game method can better reveal the formation law of credit risks among different groups of cross-border e-commerce transaction subjects.

2.3. Research on the 0ptimization Path of Cross-border E-commerce Credit Risk

From static and dynamic levels, game theory can analyze the reasons for the formation of credit risks in e-commerce and propose an optimal path to avoid risks for the industry's reference [21]. As lack of credit is a crucial factor preventing users' adoption of cross-border e-commerce, the establishment of an effective online dispute settlement mechanism is an important measure to enhance consumers' confidence in cross-border online shopping [22]. In previous studies, Agent-Swarm technology was used to conduct simulation analysis, and it was concluded that in the dynamic game of cross-border transactions, the transaction behavior would be more inclined to be more trustworthy based on the constraints of the residue mechanism [23]. A differential equation model and simulation experiment of cross-border e-commerce trade were established, and it was found that the policy attraction of new policies and regulations on the cross-border market was the first factor in promoting the effective transition from the general trade market to the cross-border market [24]. In response to that and based on existing trust assessment technology, machine learning theory, and the cloud model in Bayesian network technology, a trust model for cross-border e-commerce was proposed to effectively prevent fraud [25]. To meet the needs of the development of cross-border e-commerce in China, the government should establish multi-level supervision for small cross-border online shopping, formulate special management measures for small cross-border online shopping, build a public information inquiry platform, and accelerate the improvement of social integrity supervision mechanism and cross-border traceability mechanisms [26].

In summary, by sorting out relevant studies, scholars have discussed the credit status, formation mechanism, and resolution measures of cross-border e-commerce. However, few scholars have paid attention to the credit behavior of third-party service providers (cross-border e-commerce platforms, logistics enterprises, payment enterprises, etc.) Similarly, their relationship with regulators and influence on the supervision of regulators (governments, customs, international organizations, etc.)

have not been reported regularly. The existing literature does not pay sufficient attention to the credit risk of cross-border e-commerce. The main research contributions of this paper are as follows: First, it started from the main groups of cross-border e-commerce participants with the most complaints and concerns from consumers. That is, it studies third-party service providers and regulators of cross-border e-commerce as research subjects to expand academic research and practical value in the credit field of cross-border e-commerce. The second is to explore the relationship and law of credit behavior in the group dynamic game between the two parties by applying the evolutionary game method. The research results provide preventive measures for formulating and implementing management strategies and policies for cross-border e-commerce supervisors to promote healthy development of the cross-border e-commerce industry.

3.Materials and Methods

3.1. Theoretical Basis

Smith and Price first proposed evolutionary game theory in 1973 as the concept of evolutionary stability strategy (ESS), which was mainly used to represent the stable state of group evolutionary games [27]. Subsequently, Taylor and Jonker proposed the replicator dynamic principle (RD) concept, describing the dynamic process of achieving steady-state convergence [28]. These two concepts constitute the core of evolutionary game theory. Unlike game theory, evolutionary game theory does not assume complete rationality or information. It can more dynamically and genuinely reflect the decision-making process of the group behavior of participants, and has been widely used in the research field [29].

The research purpose of evolutionary game theory is to explain the dynamic evolution process of a group that changes over time to to obtain the greatest benefit, and to analyze the reasons and methods of the decision-making process of this group behavior. Through theoretical exploration, it is found that the factors that have an impact on group changes include not only the regular selection mechanism presented in the evolutionary process, but also some uncertain perturbations and random phenomena, i.e. mutation. Selection and mutation are the basis of constructing evolutionary game models.

Evolutionary stable strategy (ESS) focuses on selection. Combined with the above description of the role of selection, the basic idea of evolutionary stable strategy is: Suppose that in a population, the original strategy of the overall strategy is x, and the strategy taken by the mutant is y.. The overall proportion of adopting strategy y is ε, and the income is $u(y)$, then the proportion of the original selection strategy x is $(1-\varepsilon)$, and the income is $u(x)$, where $\varepsilon \in (0,1)$; if, for any strategy $y \neq x$, there exists some $\varepsilon \in (0,1)$ such that the inequality holds for all, then the original selection strategy is an ESS.

The Replicator Dynamics Principle (RD) concentrates on mutational effects.

Combined with the above description of mutation function, RD Principle of the basic idea is: if the benefit obtained by adopting a new strategy s_i higher than the average income of the group, some participants in the original group will start to learn and imitate the new strategy s_i in order to obtain higher income, and gradually increase the proportion of the new strategy, with the proportion of the original policy has decreased even eventually tends to zero. In RD Principle, the distribution proportion of group strategy in the game is regarded as a function of time (t), which changes with the t change, and its change speed can be expressed by a dynamic differential equation as $\frac{dx_i}{dt} = [f(s_i, x) - f(x, x)]x_i$, where, $f(s_i, x)$represents the income obtained by an individual by choosing s_i , $f(x, x) = \sum xf(s_i, x)$represents the average income obtained by the group, and x_i represents the proportion of selecting the new strategy s_i.

3.2. Scenario Assumptions

Based on the theoretical foundation of evolutionary game, the evolutionary game process of cross-border e-commerce third-party service provider group and regulator group includes two possible behavioral evolution mechanisms: selection mechanism and mutation mechanism. Specifically, it can be explained as follows: in the cross-border-commerce stakeholders, including the third-party service providers and regulators. Assuming that the third-party service providers (logistics companies, payment enterprises, etc.) you can choose to be trustworthy or not, regulators (governments, customs and international organizations, etc.), can choose to attach great importance to supervision or ignore regulatory decisions.

Then, the selection mechanism is embodied in the game behavior strategy of the two groups: if the third-party service providers of cross-border e-commerce can get higher returns due to dishonesty, then increasing number of third-party service providers will join the subsequent game; in addition, if the supervisor pays more attention to the supervision and can get more payments, more supervisors will choose to participate in the later game, and vice versa. In addition, the mutation mechanism is embodied in the game formation strategy as follows: if dishonesty is the evolutionarily stable strategy chosen by most third-party service providers of cross-border e-commerce, then as sudden and trustworthy third-party service providers, they will either change their strategy or gradually disappear from the group during the process of evolution; if concentrating on the regulation is the evolutionarily stable strategy chosen by most regulators, then those who ignore the regulator as a variation will either change their strategy or gradually disappear from the group, and vice versa.

Groups with different behavioral strategies between third-party service providers and regulators of cross-border e-commerce:

The evolutionary game method can

explain the dynamic evolution of the game system between third-party service providers and regulators of cross-border e-commerce;

The game between third-party service providers and regulators of cross-border e-commerce is not just a random single-round game but a process of repeatedly revising, learning, and improving the repetitive behavior strategies of the past, to gradually reach the equilibrium state.

The two groups have no specific opponents, and there are problems such as information asymmetry, so the two parties cannot fully understand each other's information rationally.

Therefore, research on the evolutionary game of credit risk in cross-border e-commerce from the perspective of third-party service providers and regulators is consistent with the characteristics and evolution process of the evolutionary game.

3.3. Assumptions and Parameter Settings

Based on relevant literature research, it can be seen that credit risk problems such as logistics services and payment security of cross-border e-commerce have been bothering consumers, which will not only reduce consumers' credit perception of third-party service providers but also have a negative impact on the credit environment of the entire cross-border e-commerce industry. Therefore, using evolutionary game theory, basic assumptions and parameter settings can be made for the evolutionary game situation of third-party service providers and regulators of cross-border e-commerce.

Assumption 1: The third-party service provider and regulator of cross-border e-commerce are both participants of bounded rationality due to their unequal information.

Assumption 2: Strategy set of third-party service providers of cross-border e-commerce (trading platform, payment enterprises, logistics enterprises, etc.) $\theta =$ {trustworthy, faithless}; regulatory policy set (governments, customs, international organizations, etc.) $\delta =$ {emphasis on regulation, neglect regulation}.

Assumption 3: The probability of a third-party service provider of cross-border e-commerce choosing to break faith is $p(p \in [0,1])$,the probability of maintaining trust is 1-p, the proportion of the regulator choosing to attach importance to regulation is $q(q \in [0,1])$,and the probability of ignoring regulation is$1 - q$. Both$p$and$q$are functions of time t.

Assumption 4: Except for the trust-breaking of the third-party service provider and the importance of the regulator, other knowledge is common to both sides of the game.

Assumption 5: As long as the supervisor pays attention to supervision, the trust-breaking behavior of the third-party service provider will be found. However, it is difficult to do so in reality because of the influence of various factors, which can be

effectively achieved by eliminating the influence of indefinitely increasing supervision costs.

Based on the above assumption, the parameters and variables involved both sides of the game can be further summarized as displayed in Table 1.

Table 1. Parameters and variables in the game model.

The strategic set	Denotation	Meaning
Broken promises	C_2	The operating cost when the third-party service provider breaks faith
	A	The operating income when the third-party service provider breaks faith
	$f(A-B)$	The loss caused to the society by the trust-breaking of third-party service providers when supervision is ignored, f is the degree of trust-breaking and $f \geq 1$
	β	The punishment factor is the punishment intensity $\beta > 0$ for the third-party service providers breaking faith
	βf^2A	when the third-party service providers are found to be dishonest punishment when paying attention to supervision
	μ	The transfer factor, refers to the percentage of net revenue transferred to the regulator as a result of the punishment $0 < \mu \leq 1$
	$\mu\beta f^2 A$	The net income of the regulator
	p	Percentage of third-party service providers who choose dishonest behavior
Keep one's word	fC_2	The operating costs of third-party service providers when they are in good faith
	B	The operating income of third-party service providers when they keep faith
Ignore the regulation	C_1	The cost of infrastructure construction, tax preference, customs clearance audit, and other costs paid by supervisors when they neglect supervision
	C	Social benefits obtained when Regulators ignore supervision
Attaches great importance to the regulatory	kC_1	The cost paid by the supervisor when attaching importance to supervision, k is the degree of attention, and $k \geq 1$
	D	Social benefits when regulators think much of the regulation
	q	The proportion of regulators choose to focus on supervision

Referring to Table 1, the game payment matrix between third-party service providers and regulators of cross-border e-commerce can be established, as shown in Table 2.

Table 2. Game reward matrix.

	The third-party service providers of cross-border e-commerce	
	Broken promises	Keep one's word

Regulators	Attaches great importance to the regulatory	$D+\mu\beta f^2A-kC_1, A-C_2-\beta f^2A$	$D-kC_1,\ B-fC_2$
	Ignore the regulation	$C-C_1-f(A-B),\ A-C_2$	$C-C_1,\ B-fC_2$

*Note: The left is the income of the supervisor, and the right is the income of the third-party service providers of cross-border e-commerce.

3.4. Model Establishment

According to the replicator dynamic principle proposed by Taylor and Jonker and the aforementioned evolutionary game reward matrix, the replication dynamic equation for the credit risk evolution of cross-border e-commerce, also known as the Malthusian equation, can be established. It was used to describe the frequency of a strategy selected by the participants being adopted by the entire group. If the population growth rate of a strategy is better than the average population growth rate, it is adopted by an increasing number of participants. Therefore, the dynamic evolution of the game between the regulator and third-party service provider is established.

The following mathematical assumptions were made for the convenience of deducing the model. It is assumed that the expected return of the regulator choosing the strategy of attaching importance to regulatory behavior is V_1, and the anticipated return of the regulator selecting the strategy of ignoring regulatory behavior is V_2. The overall average expected return for the regulator group is $\bar{V}$. Assume that the expected return of third-party service providers in cross-border e-commerce when they choose the trust-breaking behavior strategy is W_1 and the trustworthy behavior strategy is W_2. The overall average expected return of the third-party service providers of cross-border e-commerce is $\bar{W}$. It can be concluded that the specific profit models of the regulatory group and the third-party service providers of cross-border e-commerce are as follows:

$$\begin{cases} V_1 = p(D+\mu\beta f^2A-kC_1)+(1-p)(D-kC_1) \\ V_2 = p[C-C_1-f(A-B)]+(1-p)(C-C1) \\ \bar{V} = qV_1+(1-q)V_2 \end{cases} \tag{1}$$

$$\begin{cases} W_1 = q(A-C_2-\beta f^2A)+(1-q)(A-C_2) \\ W_2 = q(B-fC_2)+(1-q)(B-fC_2) \\ \bar{W} = pW_1+(1-p)W_2 \end{cases} \tag{2}$$

According to the Malthusian dynamic equation principle combined with profit model (1) and (2), we can obtain the group evolution differential equation of the regulator's choice to pay attention to the regulatory strategy and the group evolution differential equation of the third-party service provider's trust-breaking strategy:

$$F(q)=\frac{dq}{dt}=q\left(V_1-\overline{V}\right)=q(1-q)\left\{p[\mu\,\mathrm{betaf}^2A+f(A-B)]-kC1-C+D+C1\right\}$$

(3)

$$F(p)=\frac{dp}{dt}=p\left(W_1-\overline{W}\right)=p(1-p)\left[q\,\mathrm{betaf}^2A-fC_2-(A-B)+C_2\right] \quad (4)$$

Equations (3) and (4) are the replicated dynamic equations of the credit risk evolution of cross-border e-commerce. The evolutionary game model of the credit risk of cross-border e-commerce is discussed in the latter section.

4. Analysis and Results

The replicated dynamic equations of cross-border e-commerce credit risk can consider third-party service provider groups and regulators in the repeated dynamic process of the evolution concept. The evolution result was a dynamic equilibrium of their evolution to achieve the purpose of a stable state, which requires that proportion of different groups on both sides of the game between the third-party service provider groups and regulators will not change. Therefore, stable evolution strategies can be obtained by solving the equations of the evolutionary game model and judging stability [30].

4.1. Evolution Analysis of Regulators' Credit Behavior

When the proportion of groups that adhere to regulation and those that ignore regulation remains stable, the evolution of the group behavior of regulators reaches a unilateral evolutionary equilibrium. In this case, Equation (3) is $F(q)=\frac{dq}{dt}=0$, which can be obtained as:

$$p=\frac{(k-1)C_1+C-D}{\mu\,\mathrm{betaf}^2A+f(A-B)} \quad (5)$$

$$Or: q=0 \ \ and \ \ p\neq\frac{(k-1)C_1+C-D}{\mu\,\mathrm{betaf}^2A+f(A-B)} \quad (6)$$

$$Or: q=1 \ \ and \ \ p\neq\frac{(k-1)C_1+C-D}{\mu\,\mathrm{betaf}^2A+f(A-B)} \quad (7)$$

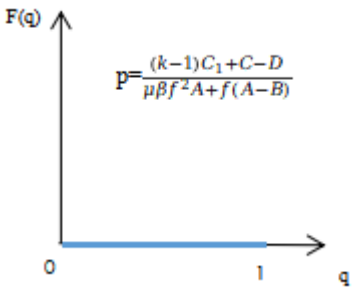
Equation (5) shows that when the proportion of the third-party service provider group adopting the trust-breaking strategy p is $\frac{(k-1)C_1+C-D}{\mu\beta f^2A+f(A-B)}$, regardless of how q changes, $F(q)$ equals to 0. Therefore, q was stable at this time. There is no difference between the regulator's choice of paying attention to the regulatory behavior strategy and ignoring the regulatory behavior strategy.

Equations (6) and (7) show that the regulator group reaches a stable state only when $q=0$ or 1.

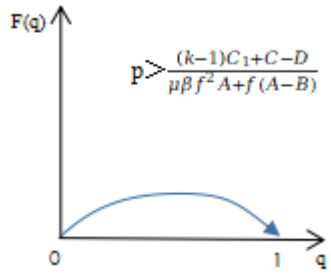
First, if $p<\frac{(k-1)C_1+C-D}{\mu\beta f^2A+f(A-B)}$, then

$F(q) = \frac{dq}{dt}(V_1 - \bar{V}) < 0, V_1 < \bar{V}$, indicating the regulation expected return that regulators attach importance to the regulatory behavior group is less than the average return of the whole regulatory group. According to the specific performance of the selection mechanism mentioned above in the game behavior strategy, it can be concluded that no regulator is willing to choose the strategy that attaches importance to supervision.Therefore, the stable state of$q = 0$is an evolutionarily stable strategy for the regulatory group. Moreover, if there are mutated individuals in the population who choose to attach importance to supervision, other regulators will not determine the strategy for dynamic learning replication behavior (i.e., they will not attach importance to supervision) because it is unprofitable. Therefore, the stable state of $q = 0$ has strong resistance to the invasion of mutated individuals, thus, the regulator group can achieve unilateral evolutionary stability. The practical significance is that the proportion of trust-breaking groups among third-party service providers of cross-border e-commerce is lower than $\frac{(k-1)C_1+C-D}{\mu\beta f^2 A+f(A-B)}$, no regulator is willing to adopt the strategy of paying attention to supervision, and the regulator gradually neglects regulatory strategies.

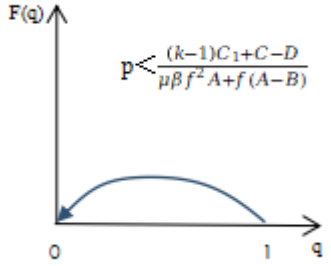
Second, if $p > \frac{(k-1)C_1+C-D}{\mu\beta f^2 A+f(A-B)}$, then $F(q) = \frac{dq}{dt} = q(V_1 - \bar{V}) > 0, V_1 > \bar{V}$,which indicates that the expected return of the group strategy of regulators choosing to pay attention to regulatory behavior is greater than the average return of the whole group of regulators. In general, regulators are willing to attach importance to regulations. Therefore, the stable state of $q = 1$ is an evolutionarily stable strategy for regulatory groups. Moreover, if there are variant individuals in the population who choose to attach importance to supervision, other regulators will determine the strategy of dynamic learning replication behavior (i.e., adopting attaching importance to supervision) because it is profitable. In this case, $q = 1$ is unstable. The practical significance is as follows: when the proportion of trust-breaking groups among third-party service providers of cross-border e-commerce is higher than $\frac{(k-1)C_1+C-D}{\mu\beta f^2 A+f(A-B)}$, all regulators are willing to adopt the strategy of attaching importance to supervision, and regulators gradually evolve to adhere to the importance to supervision strategy.



(I) No difference in the decision of regulators



(II) Regulators choose to value regulatory strategies



(III) Regulators decide to ignore the regulatory strategy

Figure 1. Stable phase diagram of the regulator evolution.

Thus, the cut-off points of the two evolutionary stable strategies $q = 0$ and $q = 1$ are $p = \frac{(k-1)C_1+C-D}{\mu\beta f^2 A+f(A-B)}$, and stable phase diagram is drawn (Figure 1).

Management implications can be obtained: there is such an implication when other parameters remain unchanged, the regulator is affected by the emphasis on regulatory benefits and neglect of regulatory benefits, reducing the neglect of regulatory benefits C, increasing the emphasis on regulatory benefits D. In other words, the smaller the demarcation point p, the smaller the proportion of cross-border e-commerce that choose untrustworthy strategies (meaning that they will tend to choose a trustworthy strategy). Therefore, regulators will gradually evolve toward attaching importance to regulatory strategies.

This influence is also valid in terms of the relationship in the context of cross-border e-commerce. If a third party of cross-border e-commerce benefits less from ignoring regulation, it will naturally choose strategy that attaches importance to regulation. Similarly, when other parameters remain unchanged, the p value of the dividing point can be reduced by increasing the net income of the supervisor, and the same effect can be achieved by evolution.

4.2. Evolution Analysis of Credit Behavior of Third-Party Service Providers

When the proportion of trust-breaking and trust-keeping groups adopted by third-party service providers in cross-border e-

commerce remains stable, the group behavior evolution of third-party service providers reaches a unilateral evolutionary equilibrium.

In this case, formula (4) $F(p)=\frac{dp}{dt}=0$can be obtained as:

$$q=\frac{(f-1)C_2+A-B}{\text{betaf}^2A} \tag{8}$$

$$Or:\ p=0\ \ and\ \ q\neq\frac{(f-1)C_2+A-B}{\text{betaf}^2A} \tag{9}$$

$$Or:\ p=1\ \ and\ \ q\neq\frac{(f-1)C_2+A-B}{\text{betaf}^2A} \tag{10}$$

Equation (8) shows that when the regulatory group adopts the strategy of attaching importance to supervision, q is $\frac{(f-1)C_2+A-B}{\beta f^2A}$. Regardless of how p changes, $F(p)$ is equal to 0. Therefore, at this time, the p value is stable, and there is no difference between the third-party service provider's choice of dishonest or trustworthy behavior strategy. Thus, the third-party service providers cannot gain more benefits through learning replicated behavior.

Equations (9) and (10) show that the group of third-party service providers reaches a stable state only when $p=0$ or $p=1$.

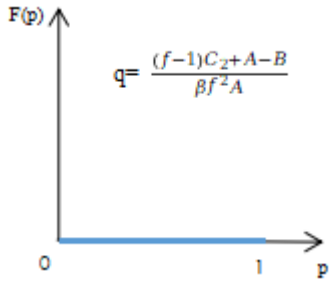
First, when $q<\frac{(f-1)C_2+A-B}{\beta f^2A}$, $F(p)=\frac{dp}{dt}=p(W_1-\bar{W})<0$, $W_1<\bar{W}$, which shows that the expected income of the service provider choosing the faithless behavior group strategy is less than the average income of the entire third-party service provider group. No third-party service provider is willing to choose a dishonest behavior strategy. Therefore, the stable state of $p=0$ is an evolutionarily stable strategy for the third-party service provider group. Moreover, if there are mutants in the population that choose dishonest behavior, other third-party service providers will not choose the dynamic learning replication behavior strategy (i.e., they will not behave faithfully) because it is not profitable. Therefore, the stable state $p=0$ has strong resistance to the invasion of mutants, thus, the third-party service provider community can achieve unilateral evolutionary stability. The practical significance is that when the proportion of the regulator group choosing to attach importance to the regulatory behavior strategy is lower than$\frac{(f-1)C_2+A-B}{\beta f^2A}$, no third-party service providers are willing to adopt the faithless strategy, and third-party service providers gradually evolve to a trustworthy approach.

Secondly, when $q>\frac{(f-1)C_2+A-B}{\beta f^2A}$, then $F(p)=\frac{dp}{dt}=p(W_1-\bar{W})>0$, $W_1>\bar{W}$. This shows that the expected income of the third-party service provider choosing the faithless behavior group strategy is greater than the average income of the third-party service provider group. In general, third-

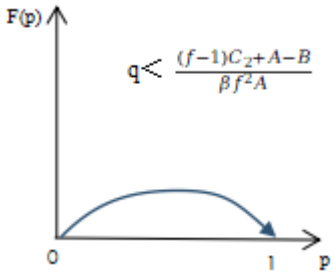
party service provider are willing to choose faithless behavior. Therefore, the stable state of $p = 1$ is an evolutionarily stable strategy for the third-party service provider group. Moreover, if there are mutated individuals in the population that choose faithless behaviors, other third-party service providers will choose a dynamic learning replication behavior strategy (i.e., they will choose faithless behaviors) because it is profitable. In this case, $p = 1$ was unstable. The practical significance is that when the proportion of the population that attaches importance to the regulatory behavior strategy is higher than $\frac{(f-1)C_2+A-B}{\beta f^2 A}$, all third-party service providers are willing to choose a faithless behavior strategy, and third-party service providers gradually evolve towards faithless behavior strategy.

Thus, the cut-off points of the two evolutionarily stable strategies $p = 0$ and $p = 1$ are $q = \frac{(f-1)C_2+A-B}{\beta f^2 A}$, and the evolution stable phase diagram of third-party service providers can be plotted (as shown in Figure 2).

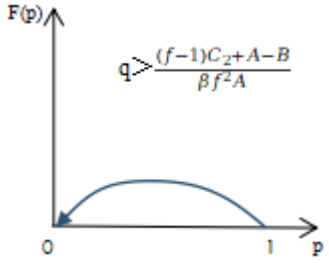
Management implications can be obtained: there is such an implication when other parameters are unchanged, third-party service providers of cross-border e-commerce are affected by trustworthy operation income and faithless operation income. Improving trustworthy operating income B and reducing untrustworthy operating income A, result in the fact that the smaller the demarcation point q, the smaller the proportion of regulators who choose to value supervision (meaning that they tend to ignore regulation), third-party service providers gradually develop at trustworthy strategy.



(IV) No difference in the decisions of regulators



(V) Regulators choose to value regulatory strategy



(VI） Regulators choose to ignore regulatory strategy

Figure 2. Evolution stable phase diagram of third-party service providers .

This type of influence is also valid from the relationship in the reality of cross-border e-commerce. If the third party of cross-border e-commerce earns more from its trust-keeping operation and less from its trust-breaking operation, it naturally tends to choose the trust-keeping strategy. Similarly, when other parameters remain unchanged, it is possible to decrease the value of q at the cut-off point by increasing the punishment intensity (increasing the punishment factor β and then evolve to achieve the same effect.

4.3. Bilateral Evolutionary Equilibrium Analysis

The final result of the evolutionary game between the third-party service provider of cross-border e-commerce and the regulator is that the entire system reaches a stable state. Therefore, formula (3) is $F(q) = \frac{dq}{dt} = 0$ and formula (4) $F(p) = \frac{dp}{dt} = 0$; the groups of both parties are combined in Fig. 1 and Fig. 2 which are presented in a coordinate plane (as shown in FIG. 3 to indicate the possible evolution process of both sides of the game at the same time and the changes to reach the equilibrium state. As can be shown in Fig. 3, different positions indicate that both sides of the game tend to choose different behavioral strategies. Both sides of the game cycle evolve around the dividing point (center point) at four positions a, b, c and d, as shown in Fig. 4.

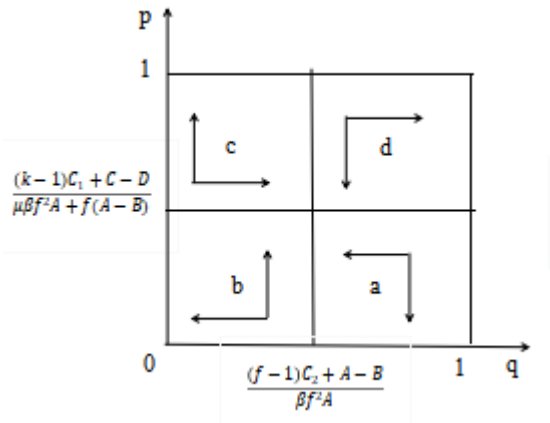


Figure 3. Bilateral evolutionary stable phase diagram(above).

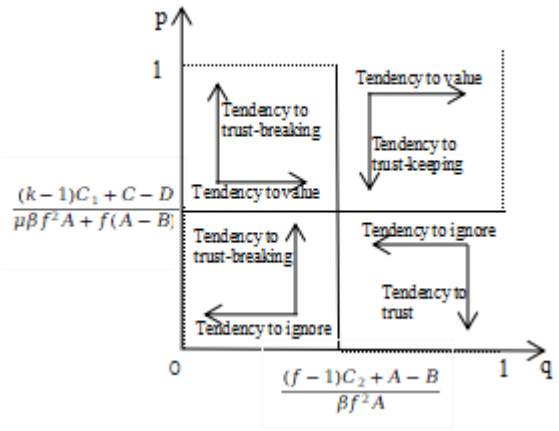


Figure 4. Changes in population structure in bilateral evolutionary equilibrium（below）.

1. When the relationship is shown in a, it means that the third-party service provider tends to choose to maintain faith, whereas the supervisor tends to ignore supervision.

2. When the q value gradually changes to 0, and $q < \frac{(f-1)C_2+A-B}{\beta f^2 A}$, p gradually approaches 1. In position b, third-party service providers tend to choose promise-breaking, and supervisors tend to ignore the supervision.

3. When the p value gradually changes to 1, and $p > \frac{(k-1)C_1+C-D}{\mu\beta f^2 A+f(A-B)}$, q gradually approaches 1. When the system evolves to position c, it means that the third-party service providers tend to choose faithless, and the supervisor tends to attach importance to supervision.

4. When q gradually changes to 1 and $q > \frac{(f-1)C_2+A-B}{\beta f^2 A}$, p gradually approaches 0. When the system evolves to position d, third-party service providers tend to choose to maintain faith and supervisors tend to attach importance to supervision.

From the above analysis, it can be seen that the position of a is the optimal state of behavioral strategy choice for both parties in the game to reduce the credit risk of cross-border e-commerce in the real market, which means that the third-party service provider is conscientious and trustworthy, and the supervisor can ignore supervision. However, this situation is unstable. When the regulator neglects supervision, the third-party service provider tends to choose a faithless behavior strategy to pursue benefits, so it is difficult to continue in position a for a long time.

As seen from the evolutionary process in Figure 4, the regulatory neglect of supervision C is reduced. In contrast, the regulatory focus on D is increased, the p value decreases, and the supervisors gradually evolve in the direction of the importance regulatory strategy. If the operating income of trustworthy B is increased and the operating income of breaking faith A is reduced, the cut-off points q decrease, and the third-party

service provider gradually evolves in the direction of a trustworthy strategy. From this point of view, location d is a realistic combination, which means that the third-party service provider tends to choose the trustworthy strategy when the supervisor attaches importance to the supervision strategy. In this state, both parties can remain in this position for a longer time.

The above deduction proves that to form good credit for cross-border e-commerce, namely low credit risk in the real environment, regulator must pay attention to the supervision of third-party service providers so that they tend to choose trustworthy behavior. To achieve this, measures such as increasing the regulator's emphasis on supervision, reducing the operating income of breaking faith, and increasing the severity of punishment can be increased. This is also in line with the development strategy for maximizing the benefits of cross-border e-commerce.

5. Discussion and Conclusions

The development of cross-border e-commerce links consumers with sellers from different cultural backgrounds, causing the process of online transactions to be affect-ed by external risks and trust factors [31]. Based on relevant literature, this study takes third-party service provider groups and regulators as research subject. The literature on cross-border e-commerce credit risk research was supplemented through the study and analysis of the dynamic evolution of credit in the two groups. It provided an optimized path for consumer complaints and cross-border e-commerce credit risk problems that are the most concerned. In other words, it offers a solution and optimization path for consumer complaints and concerns about the credit risk problems of cross-border e-commerce. The conclusion of this study are as follows:

1. Third-party service providers and regulators influence the credit risk of cross-border e-commerce, but they do not instinctively evolve to the best market scenario (i.e., third-party service providers choose to be trustworthy, and regulators can ignore supervision).
2. Cross-border e-commerce third-party service providers increase trustworthy operating income B, reduce untrustworthy operating income A, and increase punishment β, which can decrease the q value. This means that the proportion of regulators that choose to pay attention to supervision is smaller. Third-party service providers gradually evolve toward trustworthy strategies.
3. Regulators increase the operating income D by paying attention to supervision, reducing revenue by neglecting supervision C, and increasing the severity of punishment β, which can make the p value smaller. This means that proportion of cross-border e-commerce companies that choose untrustworthy strategies is smaller.
4. The third-party service providers tend to choose the trustworthy strategy when the regulator attaches importance to the supervision strategy.

Based on the above conclusions, the management enlightenment of this paper is that regulators should pay attention to the supervision of third-party service providers so that they can increase the revenue of

trustworthiness and improve the service level. The cross-border e-commerce market presents relatively good credit risk.

Although the research content of this paper is of practical value and some management enlightenment has been obtained, there are still some deficiencies, which can be further expanded in future research. First, only cross-border e-commerce participants with the most consumer complaints and concerns were selected. Third-party service providers of cross-border e-commerce and regulators were taken as the research perspective. Other participants in cross-border e-commerce need to construct and solve the evolutionary game model to fully disclose the formation mechanism of the credit risk of cross-border e-commerce. On the other hand, although this paper carried out an evolutionary game analysis of credit risk on third-party service providers and regulatory groups of cross-border e-commerce, the actual situation of the credit risk of cross-border e-commerce needs to be empirically tested to demonstrate whether it fully conforms to the rules and processes occurring in reality.

Author Contributions:

Conceptualization,F.Y.W.and.M.X.W.;methodology,F.Y.W.;analysis,F.Y.W.;writing,F.Y.W.;editing and supervision, B.S.X.T.and M.X.W.

All authors have read and agreed to the published version of the manuscript.

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