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A Species-Coexistence Model Defending against Credit Cheating in E-Commerce

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Abstract

Based on a simplified evolutionary game model, this article analyzes the internal mechanism of credit cheating behaviors in E-Commerce business. With regard to potentially technological or rule defaults in credit system as well as traders' selfish rationality, presence of credit cheating is to some extent unavoidable. We then suggest a new kind of credit system, which is independently coexistent with traders and trading, should be set up to control credit cheating. Simulation experiments support the ideas aforementioned.

Keywords: E-Commerce, Credit system, Credit cheating, Evolutionary game theory, Model of species coexistence

1. Introduction

E-Commerce was introduced into China in late of the 1990s and has begun to boom recently. However, the problem of trust has been a bottleneck constraining the development of E-Commerce. (Kiku Jones and Lori N. K. Leonard, 2008) Due to the existence of endogenous information asymmetry in E-Commerce transactions, if there is no unimpaired credit system, it is difficult for trust to diffuse quickly among traders. The problem increases transaction costs and even hinders the transaction from taking place, thereby inhibiting the growth of online trade. (Zheng Li, 2008) As a result, many well-known E-Commerce transactions website (such as Taobao, eBay, Yahoo, PaiPai and others) have set up their own credit evaluation system and dealers (about 75%) have begun to concern about the credit evaluation in the trading activities.

However, in spite of the establishment of credit evaluation system, distrust events in various forms still occur at high frequency in China. (WU Liang and WEN Jing, 2007) Because there are rule or technical loopholes in the existing credit system, a new kind of distrust behavior appears--credit cheating which is hidden and infectious. Credit cheating behaviors have a lot of forms. If these behaviors can not timely be prevented and controlled, they would seriously harm the fairness of transactions in E-Commerce market. The academic research on E-Commerce credit cheating has nevertheless not yet kept up with the real situation. Through constructing a species-coexistence model based on evolutionary game theory and carrying out simulation experiments, we analyze the internal mechanism of credit cheating behaviors in E-Commerce business.

2. Analysis on the Internal Mechanism of Credit Cheating: Based on Evolutionary Game Theory

In the 1950s, Nash and other scholars' seminal works set off a wave of game theory research. Game theory is a discipline studying individual decision-making mechanism in an environment people's decisions are influenced by each other, and calculating the equilibrium of decision-making. However, there are many defects in the traditional game theory, such as it is limited in studying the dynamic game. As a result, starting in 1970s, Smith and other scholars developed the traditional game theory and put forward the evolutionary game theory based on the theory of biological evolution. In recent years, Chinese researchers have begun to use the evolutionary game theory to analyze the trust problem in E-Commerce. (LIU Feng-ming and DING Yong-sheng, 2007)

Assuming that an E-Commerce website has set up a credit system which has potential loopholes. By taking advantage of these loopholes, traders can make themselves be untruly evaluated. The website traders can be divided into two categories--ordinary individuals and mutative individuals. Ordinary individuals are traders that choose trust behavior, and we use t to indicate them. Mutative individuals are traders that choose credit cheating behavior, and we use c to indicate them. Let $1-\varepsilon$ and ε are the proportion for t and c, respectively. The reason why we name traders who choose credit cheating acts as mutative individuals is that the credit cheating acts are often derived from some accidental factors in the course of transactions. The traders can only choose trust behavior x or distrust behavior y.

Meanwhile, the game between traders is neither perfectly information symmetric, nor information insulation, but is a game with noisy signals. At the same time, all traders are homogenous, that is which type a trader belongs to can not be judged by his or her action. According to the assumptions aforementioned, the payoff matrix between traders is showed by Figure 1.

Now we suppose: (1) The loopholes in the credit system are potential but not well-known. As a result, the trader can take free ride , that is the trader can choose distrust behavior but not be found easily, so the payoff $R < T$. (2) The traders are rational, so the payoff $P > S$.

We can then get the conclusions as follows:

Conclusion One If there are potential loopholes in the E-Commerce credit system, the traders can take free ride, that is $R < T$, thus it is impossible to realize the equilibrium in which the traders will trust each other.

Proof: The expected utility of ordinary individuals that choose trust behavior x is $\mu_t(x) = R + (S - R)\varepsilon$. The expected utility of mutative individuals that choose trust behavior is $\mu_c(x) = T + (P - T)\varepsilon$. The condition for realizing the pure strategy evolutionary stable equilibrium in which the traders choose trust behavior is:

$$\mu_t(x) - \mu_c(x) = R - T + (S - P - R + T) \cdot \varepsilon > 0 \quad (1)$$

In Equation (1), the necessary and sufficient condition for the state under which traders trust each other to become the equilibrium is $\varepsilon < \varepsilon_1 = \dfrac{R - T}{P + R - T - S}$. However, since $R < T$, the parameter ε that satisfies $\varepsilon < \varepsilon_1$ and $\varepsilon > 0$ does not exist, thus it is impossible to realize the equilibrium of trust.

Conclusion Two If the E-Commerce traders are self-concern and rational, that is $P > S$, the equilibrium in which traders make credit cheating between each other is very likely to occur.

Proof: The expected utility of ordinary individuals that choose distrust behavior y is $\mu_t(y) = P + (T - P)\varepsilon$ .The expected utility of mutative individuals that choose distrust behavior is $\mu_c(y) = S + (R - S)\varepsilon$ .The condition for realizing the pure strategy evolutionary stable equilibrium of credit cheating is:

$$\mu_t(y) - \mu_c(y) = P - S + (T - P - R + S) \cdot \varepsilon > 0 \quad (2)$$

In Equation (2), the necessary and sufficient condition for the state under which traders cheat each other to become the equilibrium is $\varepsilon < \varepsilon_2 = \dfrac{P - S}{P + R - T - S}$. Because of $P > S$, parameter ε that satisfies $\varepsilon < \varepsilon_2$ and $\varepsilon > 0$ can be found easily(a ε just less than a certain value), so it is easy to realize the equilibrium of credit cheating.

As a result, as long as there are potential loopholes in the credit system of E-Commerce website and traders are rational, the presence of credit cheating would be inevitable.

3. Defending against Credit Cheating: Based on A Species-coexistence Model

Because the credit evaluation depends excessively on the traders, the traders can cheat to get untrue credit evaluation results by using the loopholes in the credit system. Therefore, we must construct some new kind of credit system. Through comparing the three cases mentioned below, we can make clear what kind of credit system is adequate.

Case One: credit evaluation excessively depends on traders.

In this case, traders can exist independently and depend only to some extent on credit evaluation. On the contrary, credit evaluation is not independent but completely depends on the behaviors of traders. According to the Logistic Law of species evolution, the evolution equation for the quantity of traders is:

$$\dot{x}_1(t) = r_1 x_1 (1 - \frac{x_1}{N_1} + \sigma_1 \frac{x_2}{N_2}) \quad (3)$$

In Equation (3), $x_1(t)$ refers to the quantity of traders at the time point t , r_1 refers to the inherent increasing rate of the quantity, $\dot{x}_1(t)$ refers to the actual increasing rate of the quantity, x_1 and x_2 refer to the values of the quantity and the correct rate of credit evaluation in the last period, respectively. N_1 and N_2 refer to upper limits for the quantity of traders and the correct rate of credit evaluation, σ_1 refers to traders' dependency on the credit evaluation.

The evolution equation for the correct rate of credit evaluation is:

$$\dot{x}_2(t) = r_2 x_2 (-1 - \frac{x_2}{N_2} + \sigma_2 \frac{x_1}{N_1}) \quad (4)$$

In Equation (4), $x_2(t)$ refers to the correct rate of credit evaluation at the time point t, r_2 refers to the inherent increasing rate of correct rate of credit evaluation with the development of technology, $\dot{x}_2(t)$ refers to the actual increasing rate of correct rate of credit evaluation, the meaning of x_1, x_2, N_1 and N_2 are the same as mentioned in Equation (3), σ_2 refers to credit evaluation's dependency on the traders' behaviors.

Let

$$\begin{cases} \dot{x}_1(t) = r_1 x_1 (1 - \frac{x_1}{N_1} + \sigma_1 \frac{x_2}{N_2}) = 0 \\ \dot{x}_2(t) = r_2 x_2 (-1 - \frac{x_2}{N_2} + \sigma_2 \frac{x_1}{N_1}) = 0 \end{cases},$$

there are three balance points in the above equation group, that is $P_1(N_1, 0), P_2(\frac{N_1(1-\sigma_1)}{1-\sigma_1\sigma_2}, \frac{N_2(\sigma_2 - 1)}{1-\sigma_1\sigma_2}), P_3(0,0)$. According to the stability theory of differential equation [6], the stability conditions of the three solutions are:

$$\begin{cases} P_1(N_1, 0): \sigma_2 < 1, \sigma_1\sigma_2 < 1 \\ P_2(\frac{N_1(1-\sigma_1)}{1-\sigma_1\sigma_2}, \frac{N_2(\sigma_2 - 1)}{1-\sigma_1\sigma_2}): \sigma_1 < 1, \sigma_2 > 1, \sigma_1\sigma_2 < 1 \\ P_3(0,0): not\ stable \end{cases}$$

That is, when credit evaluation excessively depends on traders, there are two evolutionary stable equilibria: (1) when $\sigma_2 < 1, \sigma_1\sigma_2 < 1$, i.e. the credit evaluation's dependency on traders is less than 1 and the product of the two's interdependent degrees is also less than 1, the quantity of traders reaches to the maximal value N_1 and credit evaluation fails absolutely(the correct rate of credit evaluation decreases to zero), resulting in the prevalence of credit cheating; (2) when $\sigma_1 < 1, \sigma_2 > 1, \sigma_1\sigma_2 < 1$, i.e. the traders' dependency on credit evaluation is less than 1 and the credit evaluation's dependency on traders is more than 1, the quantity of traders and the correct rate of credit evaluation are $\frac{N_1(1-\sigma_1)}{1-\sigma_1\sigma_2}$ and $\frac{N_2(\sigma_2 - 1)}{1-\sigma_1\sigma_2}$, respectively.

Case Two: binding trade behavior with credit evaluation.

In this case, neither the traders or credit evaluation can exist independently. For example, if traders do not take part in credit evaluating or their credit evaluated result is less than a certain value, their qualification for taking part in transaction will be abolished. At the same time, the result of credit evaluation wholly depends on traders' behaviors. Therefore, the evolution equation for the quantity of traders is:

$$\dot{x}_1(t) = r_1 x_1 (-1 - \frac{x_1}{N_1} + \sigma_1 \frac{x_2}{N_2}) \tag{5}$$

The evolution equation for the correct rate of credit evaluation is:

$$\dot{x}_2(t) = r_2 x_2 (-1 - \frac{x_2}{N_2} + \sigma_2 \frac{x_1}{N_1}) \tag{6}$$

Let

$$\begin{cases} \dot{x}_1(t) = r_1 x_1 (-1 - \frac{x_1}{N_1} + \sigma_1 \frac{x_2}{N_2}) = 0 \\ \dot{x}_2(t) = r_2 x_2 (-1 - \frac{x_2}{N_2} + \sigma_2 \frac{x_1}{N_1}) = 0 \end{cases},$$

there are two balance points, that is $P_1(\frac{-N_1(1+\sigma_1)}{1-\sigma_1\sigma_2}, \frac{-N_2(1+\sigma_2)}{1-\sigma_1\sigma_2}), P_2(0,0)$. According to the stability theory of differential equation, the stability conditions of the two solutions are:

$$\begin{cases} P_1(\frac{-N_1(1+\sigma_1)}{1-\sigma_1\sigma_2}, \frac{-N_2(1+\sigma_2)}{1-\sigma_1\sigma_2}) : not\ stable \\ P_2(0,0) : always\ stable \end{cases}$$

We can then get a conclusion: when trade behavior and credit evaluation are wholly bound with each other, there is only one evolutionary stable equilibrium in which traders' quantity decreases to zero and credit cheating is prevalent. As a result, it is hard to maintain E-Commerce transaction in Case Two.

Case Three: credit evaluation independently coexists with trade behavior.

In this case, traders and credit evaluation can exist independently and promote each other. For example, the transaction qualification required for the traders depends only to a limited extent on the credit evaluation of their behaviors, and the result of credit evaluation also depends only partially on traders' behaviors. Therefore, the evolution equations for the quantity of traders and the correct rate of credit evaluation are:

$$\dot{x}_1(t) = r_1 x_1 (1 - \frac{x_1}{N_1} + \sigma_1 \frac{x_2}{N_2}) \quad (7)$$

$$\dot{x}_2(t) = r_2 x_2 (1 - \frac{x_2}{N_2} + \sigma_2 \frac{x_1}{N_1}) \quad (8)$$

Let

$$\begin{cases} \dot{x}_1(t) = r_1 x_1 (1 - \frac{x_1}{N_1} + \sigma_1 \frac{x_2}{N_2}) = 0 \\ \dot{x}_2(t) = r_2 x_2 (1 - \frac{x_2}{N_2} + \sigma_2 \frac{x_1}{N_1}) = 0 \end{cases},$$

there are four balance points, that is $P_1(N_1,0), P_2(0,N_2), P_3(\frac{N_1(1+\sigma_1)}{1-\sigma_1\sigma_2}, \frac{N_2(1+\sigma_2)}{1-\sigma_1\sigma_2}), P_4(0,0)$. According to the stability theory of differential equation, the stability conditions of the four solutions are:

$$\begin{cases} P_1(N_1,0) : not\ stable \\ P_2(0,N_2) : not\ stable \\ P_3(\frac{N_1(1+\sigma_1)}{1-\sigma_1\sigma_2}, \frac{N_2(1+\sigma_2)}{1-\sigma_1\sigma_2}) : \sigma_1\sigma_2 < 1 \\ P_4(0,0) : not\ stable \end{cases}$$

In result, when trade behavior and credit evaluation are independently coexistent, there is only one evolutionary stable equilibrium, i.e. $P_3(\frac{N_1(1+\sigma_1)}{1-\sigma_1\sigma_2}, \frac{N_2(1+\sigma_2)}{1-\sigma_1\sigma_2})$, the condition for which is $\sigma_1\sigma_2 < 1$.

Comparing the above three cases, we find that if $\sigma_1\sigma_2 < 1$, a credit system that is independently coexistent with traders is most favorable for the development of E-Commerce business. As both of them can promote each other and can also stand alone, the quantity of traders and credit evaluation system can achieve the optimal balance of coexistence. At the time, both the quantity of traders and the correct rate of credit evaluation will reach the optimal levels ($\frac{N_1(1+\sigma_1)}{1-\sigma_1\sigma_2} > \frac{N_1(1-\sigma_1)}{1-\sigma_1\sigma_2} > 0$, $\frac{N_1(1+\sigma_1)}{1-\sigma_1\sigma_2} > N_1 > 0$, $\frac{N_2(1+\sigma_2)}{1-\sigma_1\sigma_2} > \frac{N_2(\sigma_2-1)}{1-\sigma_1\sigma_2} > 0$). This can not only help the size of E-Commerce transactions expand constantly, but also effectively prevent and curb credit cheating.

4. Data simulation and analysis

The paper proves that a credit system independently coexistent with traders can effectively defend against credit cheating and promote the development of E-Commerce. Next we use Matlab7.1 to do a series of data simulation experiments to test the above conclusions.

Experiment One: Let $N_1 = 10000$ $N_2 = 0.2$ $\sigma_1 \in (0,1)$ $\sigma_2 \in (0,1)$. The values of σ_1 and σ_2 must meet the conditions of $\sigma_1\sigma_2 < 1$ and $\sigma_2 < 1$. Calculate the three cases in Section 3 for one hundred times repeatedly by stochastically choosing the values of σ_1 and σ_2. Then we get the evolutionary equilibria for the quantity of traders and the correct rate of credit evaluation. Figure 2 and figure 3 show the results.

In Figure 2 and Figure 3, the curve IC means the credit system that independently coexists with traders as described in Case Three, the curve OD means the credit system that excessively depends on traders as in Case One, the curve CT means the credit system wholly bound with traders as in Case Two. We find that as long as under certain conditions, that is $\sigma_1\sigma_2 < 1$ and $\sigma_2 < 1$, a credit system independently coexisting with traders is always superior to the other two kinds of credit systems: both the quantity of traders and the correct rate of credit evaluation are at highest levels. This result is consistent with the theoretical analysis in Section 3.

Experiment Two: Let $N_1 = 10000$ $N_2 = 0.2$ $\sigma_1 \in (0, 0.5)$ $\sigma_2 \in (1,2)$. The values of σ_1 and σ_2 must meet the conditions of $\sigma_1\sigma_2 < 1$ and $\sigma_2 < 1$. Calculate the three cases in Section 3 for one hundred times repeatedly by stochastically choosing the values of σ_1 and σ_2. Then we get the evolutionary equilibria for the quantity of traders and the correct rate of credit evaluation. Figure 4 and figure 5 show the results.

As Figure 4 and Figure 5 indicate, the result from Experiment One has no change when the dependency of credit evaluation on the traders' behaviors be beyond one, which means the result that a credit system independently coexisting with traders is always superior to the credit systems either excessively depending on traders or wholly bound with traders does not depend on the parameter σ_2 . In sum, the results of the data simulation experiments aforementioned support the theoretical analysis about the adequate relationship between the credit system and the traders.

5. Conclusions

Based on the evolutionary game theory, the paper divides E-Commerce traders into ordinary individuals and mutative individuals. By using a simplified evolution game model, we analyze the internal mechanism of credit cheating in E-Commerce business. We then construct a species-coexistent model, identifying what kind of relation credit evaluation should maintain with traders in order to effectively defend against credit cheating. The results of the model are supported by the simulation experiments. Our finding can be concluded as follow: although the emergence of credit cheating is unavoidable, credit cheating can be defended effectively by constructing a new kind of credit system independently coexistent with the traders. In the further research, we will concentrate on the topics like constructing the warning model for credit cheating in E-Commerce, and how to improve credit evaluation systems with various forms of credit cheating behaviors.

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		(Trader j)	
		Trust behavior x	Distrust behavior y
(Trader i)	x	R , R	S , T
	y	T , S	P , P

Figure 1. Payoff Matrix for Game between Traders in E-Commerce

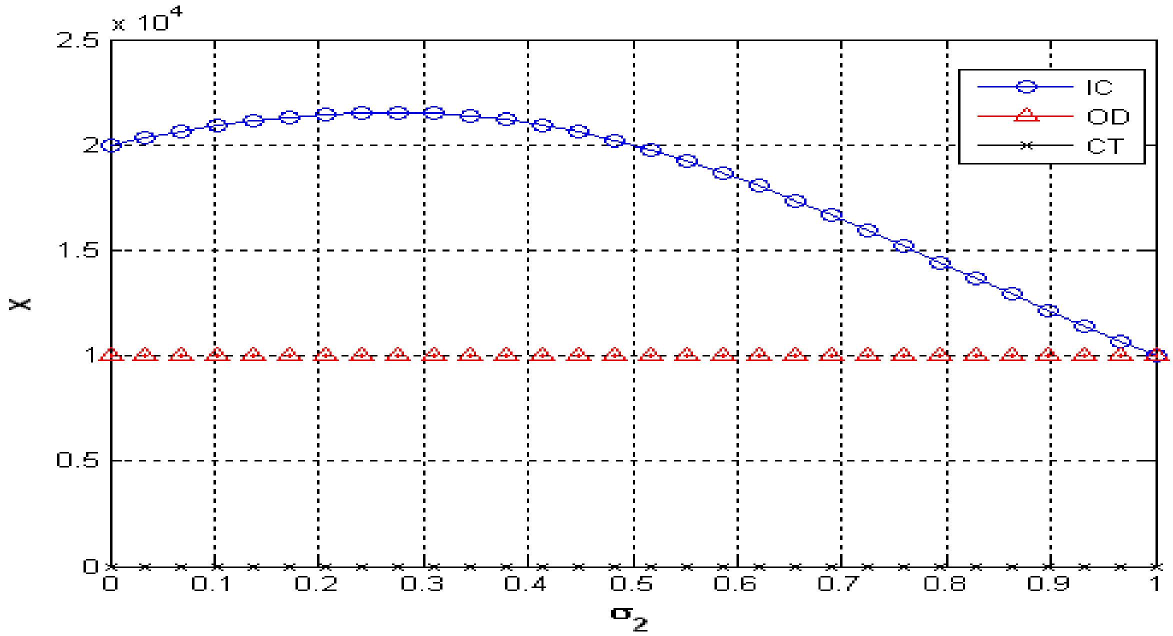

Figure 2. Quantity of Traders in Different Credit System

($\sigma_1\sigma_2 < 1$, $\sigma_2 < 1$)

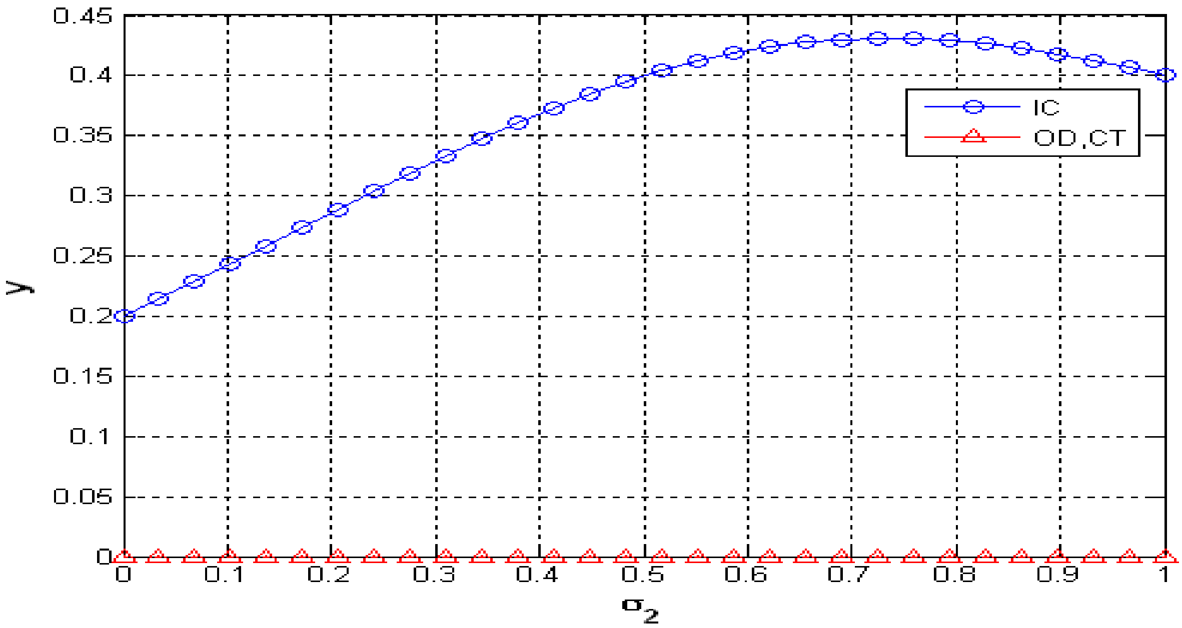

Figure 3. Correct Rate of Credit Evaluation in Different Credit System

($\sigma_1\sigma_2 < 1$, $\sigma_2 < 1$)

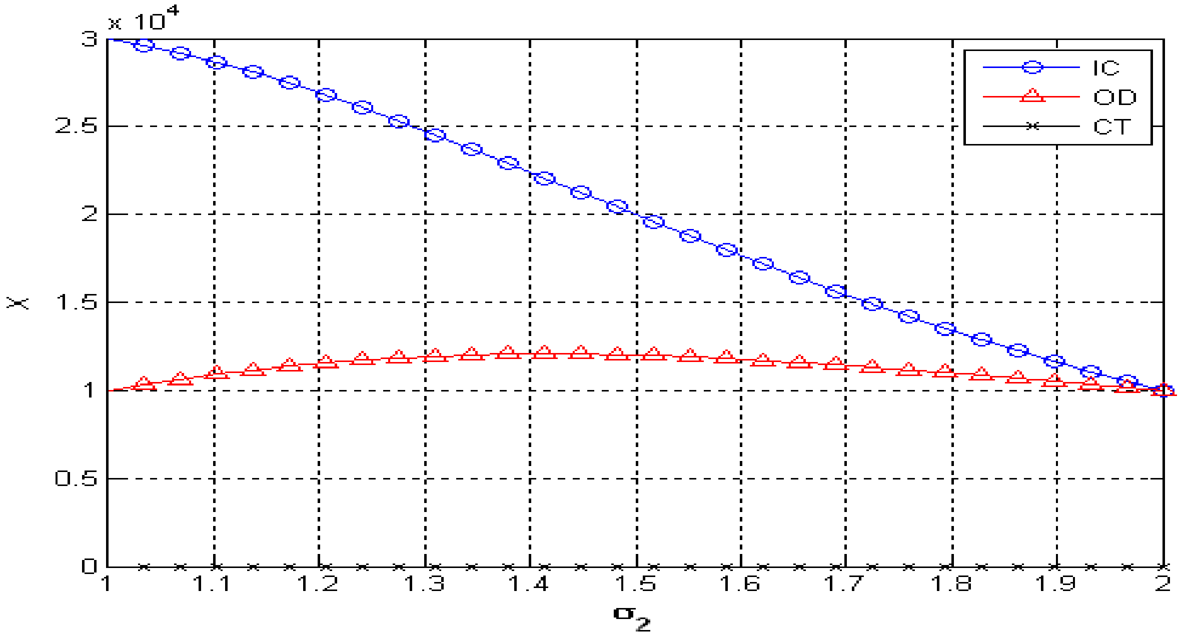

Figure 4. Quantity of Traders in Different Credit System

($\sigma_1\sigma_2 < 1$ and $\sigma_1 < 1$, $\sigma_2 > 1$)

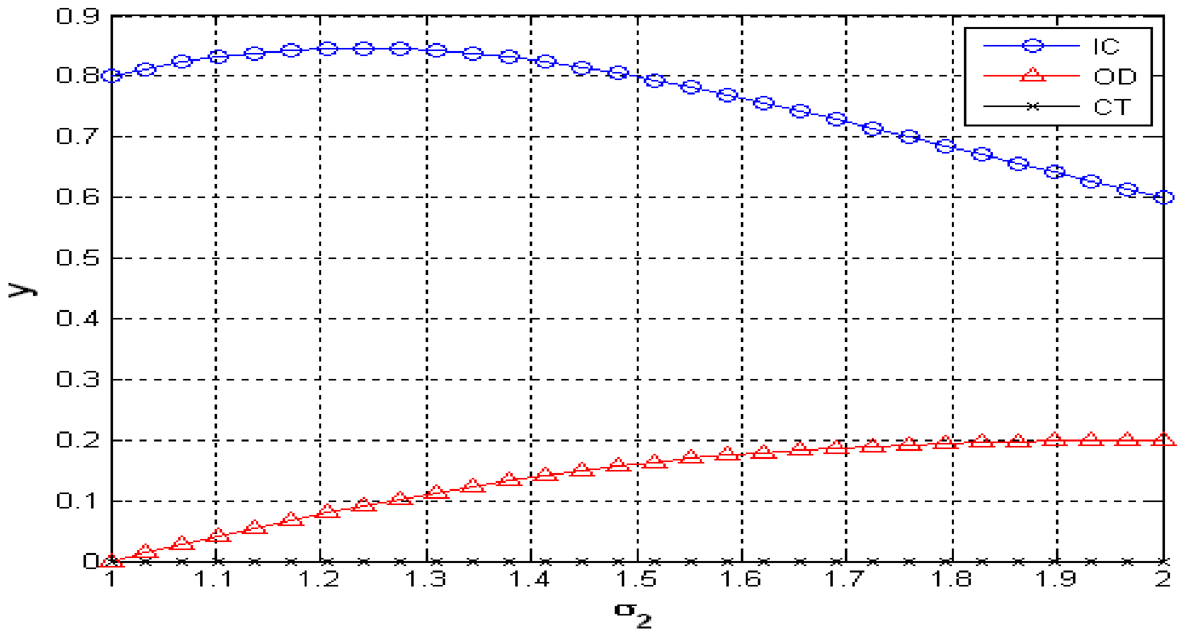

Figure 5. Correct Rate of Credit Evaluation in Different Credit System

($\sigma_1\sigma_2 < 1$ and $\sigma_1 < 1$, $\sigma_2 > 1$)