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Research Article

A New Credit and Loan Lending Strategy and Credit in Banking Systems: An Evolutionary Game Theory Approach

Zohreh Lashgari, Alireza Bahiraie, and Madjid Eshaghi Gordji

Department of Mathematics, Faculty of Mathematics, Semnan University, Semnan 35195-363, Iran

Correspondence should be addressed to Zohreh Lashgari; z.lashgari@semnan.ac.ir

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In this paper, authors offer one novel mathematical model of credit lending to customers based on evolutionary game theory, and the model presents an efficient and realistic approach. The purpose of the article is to examine the evolutionary game between banks and customers for granting facilities and credit. Authors assumed that customers are divided into two types. The first type of customers includes individuals or small and medium enterprises (SME), applying for microloans from the bank. The second type of customers includes corporate banking or large enterprises, applying for large loans from the bank. The relationship between the bank and the customers is a double-sided problem. Banks and customers may trust each other or want to behave opportunistically. The results show that the game has two equilibriums, and the optimal equilibrium, which is the best-case scenario, occurs when customers and bank players tending to keep "honest" and to "credit," respectively. Authors used the evolutionary stable strategy to express the parameters that affect these interactions, and by adjusting some of these parameters, authors move the equilibrium towards the optimal solution of the game. Also, by adjusting these parameters, banks can gain more profitability.

1. Introduction

Financial institutions have faced problems over the years for different reasons in giving credit to customers, and the main reason for these problems is lack of attention to loosen credit standards for borrowers, poor risk management, and lack of attention to changes in economic conditions or other conditions. The relationship between banks and customers is a very important factor in the economic growth of countries [1]. In the interaction between banks and customers, trust and opportunism are two important elements. In an interaction, if one party knows that the other trusts him, he may treat him opportunistically or vice versa. And the intentions of the players and their behavior determine these concepts. The degree of trust and the integrity factor in this interaction can be checked [2]. Using evolutionary game theory, we model the relationship between the bank and customers to have an optimal strategy. Game theory is a mathematical and economical approach that analyzes interactions involving strategic financial decision-making. This interaction is called a game. The parties included in the game are the players, who can be persons or groups. The players are assumed to act rationally. A rational player is one who creates decisions based on what will give themselves the most significant benefit [3].

A mathematical tool is the game theory, which analyzes and explains situations and conditions of conflict, cooperation, and coordination. Analysis and understanding of situations in which decision-makers are interacting are one of the goals of game-theoretic. The scope of game theory is extensive from a game or a daily competitive activity and supplies an answer to the complicated problem of finding a set of optimal decision-making strategies in a group or population. However, people rarely choose these strategies and modify their strategies based on their feelings and experiences. Game theory has controlled many areas, from economics (historically, its initial focus) to political science to biologies, such as business, wireless networks, computer science, psychology, and humanitarian operations [4–8].

In this article, using the theory of evolutionary games, we seek to find the optimal strategy in the interaction between the bank and customers to grant facilities and credit. Our motivation is to find the optimal solution based on evolutionary game theory in economic interactions to provide facilities so that both sides of the game can reach the optimal solution. The article contains thoughtful and new information based on mathematics, which improves performance in the interactions between the bank and the customer. The view presented in the article has many applications in the banking industry and at the same time improves performance for both the bank and the customers. The results show that the game has two equilibriums, and the optimal equilibrium, which is the best-case scenario, occurs when customers and bank players tending to keep "honest" and to "credit," respectively. By using the evolutionary sustainable strategy, the effective parameters on these interactions have been explained, and by adjusting some of these parameters, we advance the balance towards the optimal solution of the game. Also, by adjusting these parameters, banks can gain more profitability. This article answers the following questions:

(i) Can the optimal strategy for interaction between banks and customers be found with the help of an evolutionary game theory solution?

(ii) Is it possible to express the parameters affecting the interactions between the bank and customers using an evolutionary stable strategy?

(iii) Is it possible to lead banks to greater profitability by adjusting some parameters?

There are models for the relationship between banks and customers using game theory. The model presented in this article for interactions between the bank and customers to receive facilities is a complete, logical, and close to reality model. Because if we compare this model with the Nash model, we can see that both sides have chosen their strategy based on their opinion, but in the proposed model, both sides have their strategy. Also, in the Nash model, the players represent the real players, but in our model, the players (bank and company) represent the players who are randomly selected from the population, and since, the optimal strategy for these two players in a community is examined, Therefore, our model that represents this choice is a logical model and close to reality. The Nash model does not pay much attention to the mechanism of change over time, but our model examines changes in the strategy of a representative population over time. Also, in the Nash model, equilibrium is obtained, but in the proposed model, ESS is obtained, which is a more general state of Nash equilibrium. By comparing this model with the Nash model, we found that this model is an efficient model for investigating the interactions between banks and companies for granting facilities, and this model can be used to predict the behavior of banks and companies in order to receive facilities.

2. Literature Review

There is a dynamic evolutionary game (can be written in short DEG) between banks and firms. For example, in an article, this game is examined between two players whose mutual relations are in conflict. According to replicator dynamics, it has been shown that firms and banks have predator-prey interactions of the Lotka-Volterra type [9]. The dynamic interpretation of the equilibrium in this model compares banks to prey and companies to hunters. But the model presented in our article, the equilibrium obtained, is such that it leads banks and companies to the best strategy that has the maximum benefit for both parties.

In 2010, Araujo expanded an EGT approach to combating money laundering. This study assumes an evolutionary game between financial institutions and employees of the institution, in which the strategy of employees and banks to combat money laundering is examined. Players can review their strategies in each time period and compare their outcomes with the average outcome. This article illustrates that the effectiveness of the fight against money laundering depends on the inclusion of factors such as the proper design of antimoney laundering regulations and the internal willingness of banks and workers to combat this war. As a result, there is a relationship between the number of banks that want to fight money laundering and the number of employees that fight money laundering, and they influence each other [10].

In 2014, Zandi et al. wrote a theoretical model of a strategic game for market segmentation with application in banking in emerging economies. They have trouble deciding on the main customers who are the most likely buyers of their products and services. This paper proposes a new multicriteria method for the fuzzy group to enter the market and evaluate and select the segment. The proposed method provides a comprehensive and systematic framework that combines two-level multiobjective optimization with real-time option analysis and fuzzy n-player cooperative game theory [11].

In 2014, Dahlstrom et al. wrote a paper on trust in the banking industry, a game theory approach, for empirical analysis of the relationship between corporate customers and the bank. Bank managers and corporate customers are faced with the issue of confidence or uncertainty. A very important factor in the banking industry is trust because many economic transactions are risky, and it is important that the corporate customers trust the bank because trust is a factor in reducing risk and that helps managers. The article states that trust in the banking industry is one of the most important pillars. In relationships between banks and corporate customers, there may be opportunistic behavior or trust, and the purpose of this article is to examine these issues. This article first describes the prisoner's dilemma game and models the game between the bank and the company's customers based on it and states the strategy of each of them. The prisoner's dilemma is one example that has been used and analyzed many times in game theory, and it explores why two people who are rational may not cooperate together, even though it is in their best interest to cooperate together. In banking, the risk of falling into the trap of a prisoner's dilemma depends on the trust and opportunism of both parties. The model described in the article is as follows:

$$\begin{aligned}\text{Risk} = \alpha + \beta_1 T_C + \beta_2 T_B + \beta_3 O_C + \beta_4 O_B + \beta_5 O_C O_B \\ + \beta_6 T_C T_B + \beta_7 T_C O_B + \beta_8 T_B O_C + \epsilon.\end{aligned} \tag{1}$$

This study demonstrates the application of the prisoner's dilemma game to the relationship between the company's customers and the bank and states that the trust-trust option is the best solution [12]. This article has modeled the bank-customer relationship using game theory. While the model presented by us in this article is based on evolutionary game theory, which models the behavior of companies and banks based on the type they have, banks and companies pay attention to the profits and losses they have received from their previous relationship in their future interactions. They do a lot, so our article examines these interactions from this point of view.

In 2015, an article examined the competition or cooperation between commercial banks and big data in Chinese institutions in the context of an evolutionary game. This article discusses on collaboration or rivalry between commercial banks and Chinese e-commerce financial institutions from a dynamic game prospect. The results show that (cooperation, cooperation) is a sustainable evolutionary strategy and cooperation for commercial banks as well as e-commerce financial institutions in China are increasingly deep and extensive. Finally, strategic proposals for cooperation between commercial banks and e-commerce financial institutions are presented [13]. "Analysis of the Evolutionary Game of Internal Fraud in Commercial Banks (China)" was written in 2009 by Wen-xuan. Internal fraud in commercial banks is the main reason for operational risks in our country's commercial banks. With the evolutionary games, the author creates an evolutionary game model for internal fraud in a country's commercial banks [14]. An article also shows that banks can use game theory tools in bank strategic management [15].

In 2018, Hua published an article on bad loans, in which he examined the game between commercial banks and regulatory bodies using evolutionary game theory. In this study, the game between commercial banks and regulatory institutions is modeled, and then, the balance sheet is investigated [16]. "Participation against competition in the banking markets based on the theory of cooperative games" in 2018 by Khanizad and Montazer is an article that states that increasing profits and reducing operating costs are the most important issues in banking management. One way to solve this problem is for banks to work together to reduce costs and increase operating profits at the same time. To solve this problem, this paper presents a model for bank participation using game theory, in which banks can cooperate while providing their services, to achieve more profit. The model obtained from game theory is used in four private banks. The results show that the profits of banks with alliances are greater than those acting alone. Pearson correlation coefficient shows that the results of the model are consistent with the opinions of banking experts. This may reinforce the principle of "participation" versus "competition" in the banking industry [17].

In 2018, a study of the participatory game model in financial regulation was written by Lyu et al. This paper states that financial regulation is effective in controlling financial risk and promoting economic development. However, when making separate decisions, institutions tend to maximize their profits and ignore cooperation. Considering the cost-benefit ratio, this paper studies the decision to cooperate in financial regulation with the game theory method and discusses the possibility of cooperation between the central bank and regulatory bodies in different situations. Eventually, a situation arises that, over time, the likelihood of cooperation between the two sides increases. In this case, the profit of the group that does not cooperate is less than the profit when both parties cooperate [18].

A study of the relationship between banks and companies performed in 2019 by Villani and Biancardi examines a dynamic evolutionary game between banks and companies whose relationships have always been in conflict. Banks like to spend the budget to achieve the goals of the proposed projects, while companies use these loans for personal gain. This paper assumes that misbehaving companies that pursue self-interest are "hunters" and that banks are their "prey". In addition, it compares equilibrium in terms of the efficiency of Pareto efficiency calculations through average profit with some numerical applications. In 2019, Gehrig et al. were able to study banking collaboration in a study [19]. "Evolutionary Game Analysis on Corporate and Banking Behavioral Strategies: The Impact of Environmental Sovereignty on Interest Rate Determination" was published by Ye and Fang in 2021. Based on EGT, interactions and influences among rates, the regulatory interest rate of banks, and the environmental governance of companies are analyzed [20].

In an article, the authors in Poland have evaluated whether the banking sector is ready to deal with the losses caused by the development of the corporate sector in an orderly manner or not. This article explains the economic behavior of companies in providing bank debt using the main factors of microeconomics. It also shows the level of credit risk in the bank's portfolio in a period of time and examines the stress test that shows the effect of COVID-19 on the probability of default of companies. The results show that the epidemic crisis has hit all the main sectors of the economy and has increased the probability of bankruptcy of large companies, and small companies have also faced the risk of not resuming their activities after the lifting of the quarantine [21].

An article in 2022 examines the degree of concentration of credit risk on the growth of economic capital and evaluates the effectiveness of analytical methods in measuring risk. This article considers the application of additional capital costs in the case of exposure to a certain sector and the creation of restrictions in granting large loans to companies. Also, the differences between business sectors in terms of credit risk in normal conditions and conditions affected by COVID-19 are examined in this article [22].

3. Evolutionary Game Theory (EGT)

Evolutionary game theory is derived from the application of game theory in biological topics. The goal of EGT is to model the confrontation and competition between strategies with mathematical tools. The goal of EGT is to study population changes over time. In the application of evolutionary game theory to economic problems, it can be interpreted that people repeatedly play the same game and consciously change strategies, so the population changes. People are likely to change their strategies to strategies that have better outcomes and avoid strategies that have poor outcomes. The term ESS (which is short for evolutionary stable strategy) is coined by Maynard Smith, to mean that in a given population, all individuals of that population may have the same strategy phenotype. If such a strategy cannot be replaced by other strategies or attacked by another strategy through natural selection, such a strategy is an evolutionary stable strategy [23, 24]. Evolutionary games are always games consisting of several actors and, therefore, a large crowd of competitors. The important thing is that the payoff is used by different players in the next generations. Evolutionary games have significant potential for modeling fundamental economic issues.

EGT have significant potential for modeling economic issues, anthropology, sociology, financial markets, political science, social science, and many other basic sciences [25–31].

In the application of evolutionary games in economic issues, it can be interpreted that people play the same game many times and consciously change strategies; therefore, the population changes. Probably, people will change their strategies towards strategies that have better outcomes and avoid those that have poor outcomes [32].

Scientists and researchers pay special attention to evolutionary game theory because they believe that biological evolution is not the evolutionary process required by evolutionary game theory. In this situation, evolution can be considered a cultural transformation that refers to the change of norms and beliefs over time. They also believe that for modeling social systems, many of the basic assumptions of EGT rationality are more appropriate than the basic assumptions of classical game theory. And since EGT is a fully dynamic theory, this is an important factor that classical game theory lacks. EGT describes many human interactions and behavioral aspects. For modeling substantive economic issues, evolutionary games have important unrealized potential. The main difference between EGT and game theory is that in EGT, individuals or players are not rational decision-makers who choose between a number of strategies, whichever is more fit for them. Rather, each person or player has a strategy, and different people compete with different strategies. Evolutionary game theory also makes it possible to model the learning phenomenon by enabling multistage games so that after each stage, the population has the ability to change and reconsider their strategy, and many changes in human behavior have been successfully modeled with EGT.

In the EGT, the concept of ESS is the evolution of a population in which all those who play this strategy are resistant to other groups with different strategies.

Suppose function u represents a player's payoff. α is an ESS such that:

For each $\beta \neq \alpha$, there are some $\varepsilon' \in (0, 1)$, which may depend on β, such that

$$u(\alpha, \varepsilon\beta + (1-\varepsilon)\alpha) > u(\beta, \varepsilon\beta + (1-\varepsilon)\alpha). \tag{2}$$

For all $\varepsilon \in (0, \varepsilon')$. That is, α is ESS if, after a group with an opposing strategy (mutants) encounters, the group with a favorable strategy (nonmutants) is more successful than the mutants, and then, the mutants cannot attack, and eventually, they become extinct [33].

Mathematically, replicator dynamics are explicated in the form of so called replicator equations. Replicator dynamics is a group of differential equations used to study dynamics in EGT. The replicator dynamics provide a simple model of evolution in games.

The most common continuous form of the replicator equation is given by the differential equation:

$$\begin{aligned} \dot{x}_i &= x_i[f_i(x) - \phi(x)], \\ \phi(x) &= \sum_{j=1}^{n} x_j f_j(x). \end{aligned} \tag{3}$$

The continuous form of this equation is often used, and the discrete form can be obtained by processes from the discrete form [34, 35].

By simple studying, fitness is often assumed to depend linearly upon the population distribution, and according to that replicator, equation can be written in the form as follows:

$$\begin{aligned} \dot{x}_i &= x_i\left((Ax)_i - x^T A x\right), \\ \frac{d}{dx}\left(\frac{x_i}{x_j}\right) &= \frac{x_i}{x_j}\left[f_i(x) - f_j(x)\right]. \end{aligned} \tag{4}$$

This approach tries to explain the course of changes in the frequency of different species with different strategies in the population over time with mathematical equations. In replicator dynamics, strategies that perform better than average are more frequent than those that perform worse than average.

4. Evolutionary Game Approach in the Model

Our target in this paper is to explore the evolutionary game between banks and customers to grant facilities and credit. In EGT, the concept of rational behavior is not as established as in classical game theory. Banks and customers can not behave quite rationally due to (hoarding) thinking of customers. So they adopt their strategies in different situations and based on their type. Banks tend to pay loans and facilities to their customers and incur costs to do so, thereby attracting customers and ultimately making large profits. On the other hand, customers tend to receive a loan from the bank and invest in the projects they are considering and repay the bank loan according to the contract on time. But in the meantime, there are some customers who receive the loan from the bank but do not return it to the bank on time and pretend that they have failed in their investment and do not treat the bank honestly. In fact, these types of customers are looking for their own personal benefit and only consider their own interests. Therefore, the bank should consider solutions in dealing with opportunistic customers so that customers do not want to deceive the bank. In this article, we intend to introduce some parameters to encourage banks to give loans and facilities to customers and at the same time lead customers to be honest with the bank. Customers, especially corporate clients, need to apply for a loan from the bank several times, so their relationship is a long-term process, and both parties need to choose a strategy that is profitable for them. In this model, the purpose and benefits of banks are to provide credit (loan) and facilities to customers. Given that customers also repay credits to the bank on time and according to the contract and thereby gain a lot of benefits. The purpose and benefits of customers are to repay the credit to the bank. This strategy is more beneficial for them because it is an evolutionary game, and they can get credits in the next period. People working in corporate may be looking for opportunism and prioritize their benefits, or they may not fall under the sway of opportunism and choose honesty, and so the bank faces the problem. The relationship between the bank and customers can be explained by using the evolutionary game. We assume that customers are divided into two types. The first type of customers includes individual or small and medium enterprises (SME). The second type of customers includes corporate banking or large enterprises. We examine the game between the bank and customers.

The first type of customers includes SME or individuals who are applying for credit from a bank. Suppose these customers request microcredits from the bank. The second type of customers includes corporate banking or large enterprises who are applying for a credit from a bank. Suppose these customers request large credit from the bank. Bank and customers are the two players in this game who are randomly paired. Both of these players are exposed to the hypothesis of bounded rationality. We assume that banks and customers play this game in complete market conditions, and the government has no involvement in the process.

We consider two players in the game as follows:

(i) *First player*. Bank

(ii) *Second player*. Customer

The players' strategy is as follows:

(i) *Bank strategy*. {Providing credits to customers (C) and lack of credits to customers (D)}

(ii) *Customer strategy*. {Honest (C) and dishonest (D)}

"Dishonest" customer knows incorrectly that if he treats the bank honestly, they show their real behavior and type to the bank, the investment is profitable, and the project is successful, they will have to deliver the credits or profits or both to the bank. Therefore, the "dishonest" customer pretends that their project is not suitable, and their investment will fail, by cheating the bank. Bank gets the success rate of their investment projects and chooses their "providing credits" or "Lack of credits" strategies based on. That is, the bank chooses its strategy based on successful or unsuccessful customer projects and their history. Therefore, customer history is very important for a bank. We assume that in this game, bank credit interest rates remain unchanged.

5. Model

To simplify the calculations, we consider the interest rate of the bank credit in this game without any change. And banks and customers cannot behave completely logically due to asymmetry in information, so the assumption of rational behavior in the game is removed. Customers that are honest know that they have to deliver the credits and interest they received to the bank on time according to the contract. Customers that are dishonest try to deceive the bank and pretend that their investment will fail. We assume that all the debts of the customers are bank credits.

The algorithm of the described model is briefly as follows: in the first stage, the parameters are defined and introduced for both players. The second stage of the payoff game table between these two players is written in the form of a game matrix. The third stage of the replicator dynamics in the game is examined. In the fourth step, we will examine the ESS of this game and specify the results.

In Table 1, the notation and parameters of the model are shown.

In this table (Table 1), r is the credit interest rate; D represents enterprises' debt funds, and all these debts are bank credits; CD indicates the application costs of enterprises; BD indicates the bank credit costs, which represents the bank's costs when it controls companies. The profit for the enterprises that manage their project after obtaining credit and facilities from the bank is R; Dr shows the gain when all the D has been taken by the bank; P indicates the success rate of the verification. If SME or individuals are dishonest, the receipt of receivables costs for the bank is T_1. If corporate banking or large enterprises are dishonest, the receipt of receivables costs for the bank is T_2; L represents the loss of reputation, which means that it is very difficult for customers to obtain bank credit after losing a reputation. If bank players select lack of credit strategy, there will be opportunity loss for enterprises which select the strategy of "honest", which is C. Once enterprises select the strategy of dishonest, it has been investigated because of moral hazard. I represents the cost of penalty for the enterprise that chooses the dishonesty strategy; H indicates the project initial validation costs. If SME or individuals obtains the credit, the bank will have to pay the project secondary control costs, which is E_1. If corporate banking or large enterprises obtains the credit, the bank must pay for the project secondary control costs, which is E_2.

Table 1: Model parameters.

Symbol	Meaning
r	The credit interest rate
D	Customer debt funds
CD	The application costs of customers
BD	The bank credit costs
R	The benefit for the customer
Dr	The gain for the bank
P	The success rate of verification
T_1	Cost of receiving receivables from SME or individuals
T_2	Cost of receiving receivables from corporate banking or large enterprises
L	Reputation losses
C	Opportunity loss for customer
I	The penalty costs
H	The project initial validation costs
E_1	Costs of secondary controls of the project of SME or individuals
E_2	Costs of secondary controls of the project of corporate banking or large enterprises

The following relationships are established for the cost of secondary controls and cost of receiving receivables:

$$E_1 < E_2,$$
$$T_1 < T_2. \tag{5}$$

The gain matrix between bank and SME or individuals is shown in Table 2.

The gain matrix between corporate banking or large enterprises and the bank is shown in Table 3.

6. Replication Dynamic Analysis of the Model

6.1. Replication Dynamic in the Game between SME or Individuals and Bank. In the first stage of the game between SME or individuals and bank, suppose the bank players' ratio who choose "credit" strategy is x, and the bank players' ratio who choose "lack of credit" strategy is $1-x$. The customers' ratio who choose the strategy of "honest" is y, and the customers' ratio who choose the strategy of "dishonest" is $1-y$. Therefore, whenever bank players apply credit strategy, we show the payoff (expected payoff) obtained with $S(\text{do})$, which is

$$\begin{aligned} S(\text{do}) &= y(\text{PD}r - \text{BD} - H - E_1) \\ &\quad + (1-y)(\text{PI} - \text{BD} - D - H - E_1 - T_1), \\ S(\text{do}) &= y(\text{PD}r + D - \text{PI} - T_1) - D - \text{BD} - H - E_1 - T_1 + \text{PI}. \end{aligned} \tag{6}$$

When bank applies lack of credit strategy, we show the payoff obtained with $S(\text{undo})$, which is

$$S(\text{undo}) = y(-\text{PD}r + \text{BD} + H + E_1). \tag{7}$$

Therefore, the average gain $\bar{S}$ can be expressed as

$$\begin{aligned} \bar{S} = x\,&[(2\text{PD}r + D - \text{PI} - T_1 - \text{BD} - H - E_1)y + \text{PI} - D - \text{BD} \\ &- H - E_1 - T_1] + y(\text{BD} - \text{PD}r + H + E_1). \end{aligned} \tag{8}$$

Therefore, the replication equation can be as follows:

$$S'_t = x\left(S(\text{do}) - \bar{S}\right). \tag{9}$$

Thus,

$$\begin{aligned} S'_t = x\,(1-x)[&(2\text{PD}r + D - PI - H - E_1 - \text{BD} - T_1)y \\ &+ \text{PI} - D - \text{BD} - H - E_1 - T_1]. \end{aligned} \tag{10}$$

Thus, the replication dynamic equation can be represented as the above relation when the bank players' ratio selecting credit strategy is x.

When customers apply honest strategy, we show the payoff obtained with $K(\text{honesty})$, which is

$$\begin{aligned} K(\text{honesty}) &= x(\text{PR} - \text{CD} - \text{PD}r - D) + (1-x)(-C - \text{CD}), \\ K(\text{honesty}) &= x(P\text{R} - \text{PD}r - D + C) - C - \text{CD}, \\ K(\text{dishonesty}) &= x(\text{PR} - \text{PI} - L), \\ \bar{K} &= y[(-\text{PD}r - D + \text{PI} + L + C)x - C - \text{CD}] \\ &\quad + x(\text{PR} - \text{PI} - L), \\ K'_t &= y\left(K(\text{honesty}) - \bar{K}\right), \\ K'_t &= y(1-y)[x(\text{PI} + L - D - \text{PD}r + C) - C - \text{CD}]. \end{aligned} \tag{11}$$

Thus, the replication dynamic equation can be represented as the above equation when the ratio of customers selecting the strategy of "honest" is y.

6.2. Replication Dynamic in the Game between Corporate Banking or Large Enterprises and Bank. According to a similar argument, in the game between corporate banking or large enterprises and banks in the first stage, suppose the bank players' ratio who choose "credit" strategy is x', and the bank players' ratio who choose "lack of credit" strategy is $1-x'$. The customers' ratio who choose the strategy of "honest" is y', and the customers' ratio who choose the strategy of "dishonest" is $1-y'$. Therefore, whenever bank

Table 2: Game matrix.

Bank	SME or individuals	
	Honest	Dishonest
Credit	$\mathrm{PD}r - \mathrm{BD} - H - E_1, \mathrm{PR} - CD - D - \mathrm{PD}r$	$\mathrm{PI} - \mathrm{BD} - D - H - E_1 - T_1, \mathrm{PR} - \mathrm{PI} - L$
Lack of credit	$-\mathrm{PD}r + \mathrm{BD} + H + E_1, -C - \mathrm{CD}$	0, 0

The parameters of the table represent the profits of banks and SME or individuals when they choose their strategies.

Table 3: Game matrix.

Bank	Corporate banking or large enterprises	
	Honest	Dishonest
Credit	$\mathrm{PD}r - \mathrm{BD} - H - E_2, \mathrm{PR} - \mathrm{CD} - D - \mathrm{PD}r$	$\mathrm{PI} - \mathrm{BD} - D - H - E_2 - T_2, \mathrm{PR} - \mathrm{PI} - L$
Lack of credit	$-\mathrm{PD}r + \mathrm{BD} + H + E_2, -C - \mathrm{CD}$	0, 0

The parameters of the table represent the profits of bank and corporate banking or large enterprises when they choose their strategies.

players apply the lending strategy, we show the payoff (expected payoff) obtained with $G(\mathrm{do})$, which is

$$G(\mathrm{do}) = y'(\mathrm{PD}r - \mathrm{BD} - H - E_2) + \left(1 - y'\right)(\mathrm{PI} - \mathrm{BD} - D - H - E_2 - T_2),$$
$$G(\mathrm{do}) = y'(\mathrm{PD}r + D - \mathrm{PI} - T_2) - D - \mathrm{BD} - H - E_2 - T_2 + \mathrm{PI}. \tag{12}$$

When bank applies the lack of credit strategy, we show the payoff obtained with $G(\mathrm{undo})$, which is

$$G(\mathrm{undo}) = y'(-\mathrm{PD}r + \mathrm{BD} + H + E_2). \tag{13}$$

Thus, $\bar{G}$ can be expressed as

$$\bar{G} = x'\left[(2\mathrm{PD}r + D - \mathrm{PI} - T_2 - \mathrm{BD} - H - E_2)y' + \mathrm{PI} - D - \mathrm{BD} - H - E_2 - T_2\right] + y'(\mathrm{BD} - \mathrm{PD}r + H + E_2). \tag{14}$$

Therefore, the replication equation can be as follows:

$$G_t' = x'\left(G(\mathrm{do}) - \bar{G}\right). \tag{15}$$

Thus,

$$G_t' = x'\left(1 - x'\right)\left[(2\mathrm{PD}r + D - \mathrm{PI} - H - E_2 - \mathrm{BD} - T_2)y' + \mathrm{PI} - D - \mathrm{BD} - H - E_2 - T_2\right]. \tag{16}$$

Thus, the replication dynamic equation can be represented as the above equation when the ratio of bank selecting credit strategy is x'.

When customer players apply the honest strategy, we show the payoff obtained with $M(\text{honesty})$, which is

$$M(\text{honesty}) = x'(\mathrm{PR} - \mathrm{CD} - \mathrm{PD}r - D) + \left(1 - x'\right)(-C - \mathrm{CD}),$$
$$M(\text{honesty}) = x'(\mathrm{PR} - \mathrm{PD}r - D + C) - C - \mathrm{CD}. \tag{17}$$

When customers apply the dishonest strategy, we show the payoff obtained with $M(\text{dishonesty})$, which is

$$M(\text{dishonesty}) = x'(\mathrm{PR} - \mathrm{PI} - L). \tag{18}$$

Thus, for the customers selecting the honest strategy, the average gain $\bar{M}$ can be expressed as

$$\bar{M} = y'[(-\mathrm{PD}r - D + \mathrm{PI} + L + C)x - C - \mathrm{CD}] + x'(\mathrm{PR} - \mathrm{PI} - L). \tag{19}$$

Therefore, the replication equation can be as follows:

$$M_t' = y'\left(M(\text{honesty}) - \bar{M}\right). \tag{20}$$

So,

$$M_t' = y'\left(1 - y'\right)\left[x'(\mathrm{PI} + L - D - \mathrm{PD}r + C) - C - \mathrm{CD}\right]. \tag{21}$$

Thus, the replication dynamic equation can be represented as the above equation when the ratio of customers selecting the strategy of "honest" is y'.

7. ESS Analysis of the Model

7.1. ESS in the Game between SME or Individuals and Bank. Suppose $S_t' = 0$, so we get a solution for it. When the bank players' ratio selecting the credit strategy is x, we examine the evolutionary stable analysis. According to the definition of the ESS and the stability intent of the differential equations, when

$$y = \frac{-\mathrm{PI} + D + \mathrm{BD} + H + E_1 + T_1}{2\mathrm{PD}r + D - \mathrm{PI} - H - E_1 - \mathrm{BD} - T_1}, \quad S_t' = 0. \tag{22}$$

The gains of the bank players who choose the credit strategy and the average gains on this side are equal. So if there are no more useful conditions for improvement, banks will keep their strategies and are reluctant to change them.

When

$$y > \frac{-\mathrm{PI} + D + \mathrm{BD} + H + E_1 + T_1}{2\mathrm{PD}r + D - \mathrm{PI} - H - E_1 - \mathrm{BD} - T_1}, S_t' > 0, \tag{23}$$

which means $S_t' > \bar{S}$. In this case, the gains for bank players selecting the credit strategy are higher than the average gains as well. Consequently, bank players will gently discover this fact, learn, and imitate to adjust their choices. After a while, the individual bank players' ratio selecting the credit strategy is 1, and in this case, $x = 1$ is an ESS and is the required solution. These conditions are displayed in Figure 1.

When

$$y < \frac{-\mathrm{PI} + D + \mathrm{BD} + H + E_1 + T_1}{2\mathrm{PD}r + D - \mathrm{PI} - H - \mathrm{E}_1 - \mathrm{BD} - T_1}, S_t' < 0, \tag{24}$$

which means $S_t' < \bar{S}$. In this case, the gains for bank players selecting the credit strategy are lower than the average gains as well. Consequently, bank players will gradually and over time discover this fact and adjust their choices. After a while, the individual bank players' ratio selecting the credit strategy is 0, that is, bank players selecting the lack of credit strategy, and in this case, $x = 0$ is an ESS. These conditions are displayed in Figure 2.

Suppose $K_t' = 0$, so we get a solution for it. ESS analysis when the ratio of customer players selecting the strategy of "honest" is y.

When

$$x = \frac{\mathrm{CD} + C}{\mathrm{PI} + L - D - \mathrm{PD}r + C}, K_t' = 0. \tag{25}$$

The gains of the customer players who choose the strategy of "honest" and the average gains on this side are equal. Customers will keep their strategies and are reluctant to change them.

When

$$x > \frac{\mathrm{CD} + C}{\mathrm{PI} + L - D - \mathrm{PD}r + C}, K_t' > 0, \tag{26}$$

which means $K_t' > \bar{K}$. In this case, the gains for customers selecting the strategy of "honest" are higher than the average gains on this side as well. After adjustment, the customers' ratio selecting the strategy of "honest" on this side is 1, and

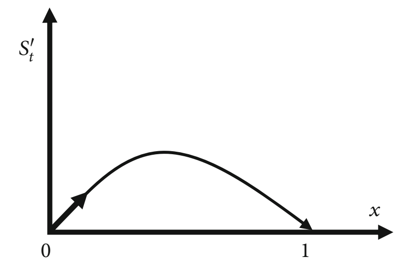

Figure 1: Bank selects the credit strategy.

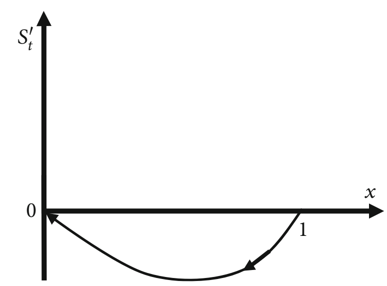

Figure 2: Bank selects the lack of credit strategy.

in this case, $y = 1$ is an ESS. These conditions are displayed in Figure 3.

When

$$x < \frac{\mathrm{CD} + C}{\mathrm{PI} + L - D - \mathrm{PD}r + C}, K_t' < 0, \tag{27}$$

which means $K_t' < \bar{K}$. The gains for customers selecting the strategy of "honest" are lower than the average gains on this side. After a while, the customers' ratio selecting the strategy of "honest" on this side is 0, that is, customers selecting the dishonest strategy, and in this case, $y = 0$ is an ESS. These conditions are displayed in Figure 4.

7.2. ESS in the Game between Corporate Banking or Large Enterprises and Bank. Suppose $G_t' = 0$, so we get a solution for it. When the bank players' ratio selecting the credit strategy is x', we examine the evolutionary stable analysis. Similar to the argument above, when

$$y' = \frac{-\mathrm{PI} + D + \mathrm{BD} + H + E_2 + T_2}{2\mathrm{PD}r + D - \mathrm{PI} - H - E_2 - \mathrm{BD} - T_2}, G_t' = 0. \tag{28}$$

The gains of the bank players who choose the credit strategy and the average gains on this side are equal. Therefore, bank players keep this strategy if there are no better conditions.

When

$$y' > \frac{-\mathrm{PI} + D + \mathrm{BD} + H + E_2 + T_2}{2\mathrm{PD}r + D - \mathrm{PI} - H - E_2 - \mathrm{BD} - T_2}, G_t' > 0, \tag{29}$$

which means $G_t' > \bar{G}$. In this case, the gains for bank players selecting the credit strategy are higher than the average gains as well. Consequently, bank players will gradually and over

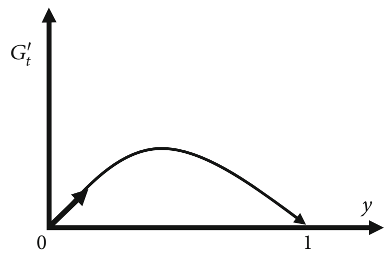

Figure 3: Customers select honest strategy.

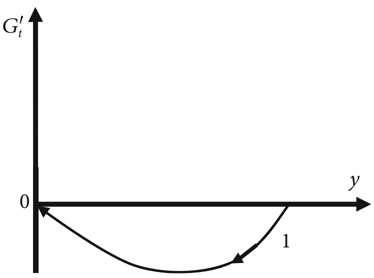

Figure 4: Customers select dishonest strategy.

time discover this fact, learn, and imitate to adjust their choices. After a while, the individual bank players' ratio selecting the credit strategy is 1, and in this case, $x' = 1$ is an ESS and is required solution. These conditions are displayed in Figure 5.

When

$$y' < \frac{-\mathrm{PI} + D + \mathrm{BD} + H + E_2 + T_2}{2\mathrm{PD}r + D - \mathrm{PI} - H - E_2 - \mathrm{BD} - T_2}, G_t' < 0, \quad (30)$$

which means $G_t' < \bar{G}$. In this case, the gains for bank players selecting the credit strategy are lower than the average gains as well. Consequently, bank players will gently discover this fact and adjust their choices. After a while, the individual bank players' ratio selecting the credit strategy is 0, that is, bank players selecting the lack of credit strategy, and in this case, $x' = 0$ is an ESS. These conditions are displayed in Figure 6.

Suppose $M_t' = 0$, so we get a solution for it. ESS analysis when the ratio of customers selecting the strategy of "honest" is y'.

When

$$x' = \frac{\mathrm{CD} + C}{(\mathrm{PI} + L - D - \mathrm{PD}r + C)}, \quad M_t' = 0. \quad (31)$$

The gains of the customer players who choose the strategy of "honest" and the average gains in this group are equal. Customers will keep their strategies and are reluctant to change them.

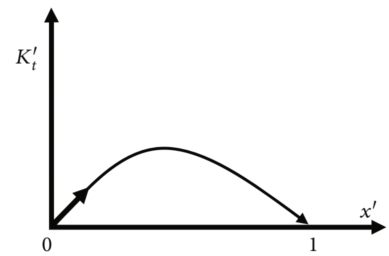

Figure 5: Bank selects the credit strategy.

When

$$x' > \frac{\mathrm{CD} + C}{(\mathrm{PI} + L - D - \mathrm{PD}r + C)}, M_t' > 0, \quad (32)$$

which means $M_t' > \bar{M}$. In this case, the gains for customers selecting the strategy of "honest" are higher than the average gains on this side as well. After adjustment, the customers' ratio selecting the strategy of "honest" on this side is 1, and in this case, $y' = 1$ is an ESS. These conditions are displayed in Figure 7.

When

$$x' < \frac{\mathrm{CD} + C}{(\mathrm{PI} + L - D - \mathrm{PD}r + C)}, M_t' < 0, \quad (33)$$

which means $M_t' < \bar{M}$. The gains for customers selecting the strategy of "honest" are lower than the average gains on this side. After a while, the customers' ratio selecting the honest strategy on this side is 0, that is, customers selecting the dishonest strategy, and in this case, $y' = 0$ is an ESS. These conditions are displayed in Figure 8.

8. Decision-Making

There are general evolutionary stable strategies for both games in this model. According to the replicator equation between the bank and customers, there are two evolutionary stable strategies, which are points $(0, 0)$ and $(1, 1)$. The strategy $(1, 1)$ is the equilibrium we are considering in this model, which this equilibrium means customers and bank players tend to keep "honest" and to "credit", respectively. And this is the best-case scenario. The strategy $(0, 0)$ means that all customers would like to choose dishonest strategy, and a bank want to choose a lack of credit strategy, which is an undesirable equilibrium. We intend to provide the conditions for a sustainable evolutionary stable strategy by analyzing the parameters of the model and adjusting the parameters.

In both games, when the initial validation costs of bank H increase, the probability that the system will reach an ESS $(0, 0)$ will enlarge. Vice versa, when BD decreases, the probability that the system will reach an ESS $(1, 1)$ will enlarge. This is also understandable in reality; for example, when banks have to pay high initial validation costs and management verification costs, their checking and review power is reduced. Therefore, by reducing initial validation

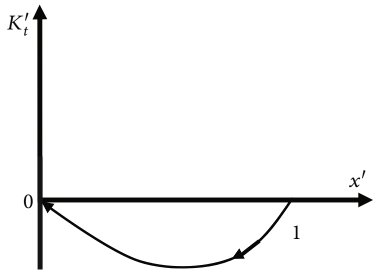

Figure 6: Bank selects the lack of credit strategy.

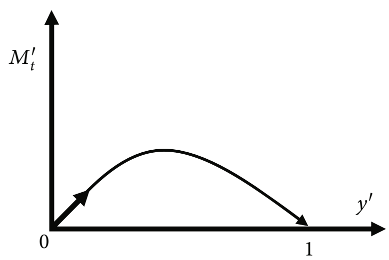

Figure 7: Customers select honest strategy.

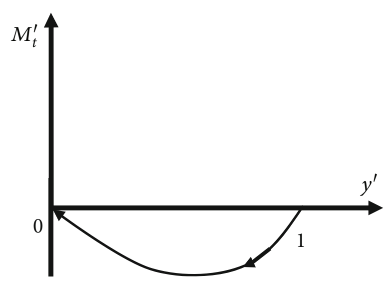

Figure 8: Customers select dishonest strategy.

costs and reducing the credit costs for the bank, the equilibrium goes to $(1, 1)$. Similarly, when the secondary control costs of bank E_1 and E_2 increase, the probability that the system reaches an ESS $(0, 0)$ will enlarge. Therefore, by reducing the costs of secondary control of the bank, the equilibrium goes to $(1, 1)$. To do this, monitoring can be done inhumanely and a system that costs less. According to the above analysis, when parameter C increases, the probability that the system will reach an ESS $(1, 1)$ will enlarge. Vice versa, when parameter C declines, meaning that the opportunity loss is reduced, the probability that the system will reach an ESS $(0, 0)$ will enlarge.

When parameter I increases, the probability that the system will reach an ESS $(1, 1)$ will enlarge. Vice versa, when parameter I declines, the probability that the system will reach an ESS $(0, 0)$ will enlarge. Therefore, stricter conditions should be set for the dishonest customers; for example, no credit type should be granted by the bank to the offending customers. Therefore, by doing so, customers will not be willing to provide dishonest information to obtain a credit. Many economic models have shown that the economic tool is the most effective tool among all tools against the ruling criminals in society, so this solution can be effective.

When parameter L increases, the probability that the system reaches an ESS $(1, 1)$ will enlarge. Vice versa, when parameter L declines, the probability that the system will reach an ESS $(0, 0)$ will enlarge. Therefore, they make the conditions for lending to dishonest customers more difficult; for example, if the reputation of customers is damaged, their history will be revealed to the bank, and these customers will not be able to get a credit from the bank.

9. Conclusions

This article describes two evolutionary games. It is a game between bank and individual or SME. The next game is between a bank and corporate banking or large enterprises. Evolutionary stable strategies for both games modeled in this article are $(1, 1)$ and $(0, 0)$. The strategy $(1, 1)$ is the equilibrium we are considering in this model, which this equilibrium means customers and bank players tend to keep "honest" and "credit", respectively. If the strategy $(1, 1)$ is chosen, it will make the bank willing to lend credit, in which case they will make much profit, and customers will also tend to return the received loan at the time due to the bank and will be honest with the bank. And this is the solution of the game and the best scenario. The strategy $(0, 0)$ means that all customers would like to choose dishonest strategy, and the bank wants to choose lack of credit strategy, which is an undesirable equilibrium. If the strategy $(0, 0)$ is chosen, it will make the bank reluctant to lend a credit, in which case they will not make much profit, and the customers will not be willing to treat the bank honestly.

So in order to reach the solution to this game and for the bank to choose the strategy of credit to customers, it is necessary to carefully examine some effective parameters. This can be done by reducing the project initial validation costs and reducing the project secondary control costs. The next point is that the history of customers should be very important for the bank, and based on this history, their credit with the bank will be determined. Reputation losses parameter is effective in giving credit to the customer. If bank takes this approach and adjusts the parameters mentioned, they will be able to deal more successfully with customers and achieve good results by providing credits to customers.

Banks and companies may have a slightly different perception of costs, and it is possible that in addition to the variables stated in this article, other variables may have an impact on this financial information. But despite the existence of these limitations, because the differences are not too great, and the main variables of the model have been tried to be expressed, the new method presented is very practical and important compared to other studies.

Data Availability

No data were used to support this study.

Disclosure

The current study received no specific grant from any funding agency, commercial, or not-for-profit sectors. No other entity besides the authors had a role in the design, analysis, or writing of the current article.

Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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