Research Article

Evolutionary Game Analysis of Debt Restructuring Involved by Asset Management Companies

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Based on the evolutionary game theory, this article constructs a quartet evolutionary game model for debt restructuring with the participation of asset management companies; studies the interactive mechanism of complex behaviors among the government, banks, asset management companies, and enterprises; and analyzes the stability of the strategies of each game subject. It also analyzes the stability of the equilibrium points in the system and finds the stable points that maximize the interests of each subject. Research shows that the government chooses to give specific support, banks choose debt-to-equity swaps, asset management companies choose to provide liquidity, and enterprises choose to work hard, which can better promote the debt restructuring process. Finally, using Matlab2018 software to analyze the impact of each essential element in the debt restructuring on the stability of system evolution, the research results provide a basis for the successful debt restructuring of the enterprises.

1. Introduction

With the development of economic globalization, the complexity of enterprise decision-making is increasing. The probability of enterprise decision-making mistakes is constantly increasing, which leads to the increase of the probability of high debt and makes enterprises fall into financial crisis. Debt restructuring is a critical way to revitalize enterprises in financial difficulties and avoid bankruptcy liquidation. After the global financial crisis, debt restructuring has become an essential topic of discussion among academics and practitioners [1].

At present, most scholars have conducted research on debt restructuring using empirical research methods, mainly focusing on the following two aspects: (1) Research on the factors affecting debt restructuring. Mo et al. [2] find that as the strength of political connection increases from weak to strong, the positive impact of debt restructuring on investment turns to a negative impact. Bergström et al. [3] indicate that restricting the priority of secured debt may stimulate debt restructuring, and there is a negative correlation between the security of financial institution lenders and the possibility of debt restructuring. (2) Research on the role played by debt restructuring. Charalambides et al. [4] point out that the presence of a firm’s option for debt rescheduling reduces the firm value by reducing the management’s ability to raise debt. Cheng et al. [5] use the data processed by the Paris Club to study the impact of 422 official sector debt restructurings on the macro-economy and find that debt relief can affect economic growth. Mo et al. [2] find that debt restructuring alleviated the problems of over-investment and under-investment, thereby effectively improving the investment efficiency of politically connected enterprises. Debt restructuring is a complex system involving multiple parties, and it is the result of each participating in a common game. Based on the successful results of the above studies, it is found that there is currently less research on the strategic choices of all parties to debt restructuring, and there are few people studies on the process of asset management companies participating in debt restructuring. Asset management companies are specialized institutions that help enterprises solve debt problems, deal with enterprise nonperforming assets, and deepen enterprise reform. They have extensive experience in handling debt restructuring [6].

The debt restructuring process of many large enterprises at home and abroad requires the participation of asset
management companies. However, few scholars systematically analyze the dynamic process of government, banks, asset management companies, and enterprises’ participation in debt restructuring. The evolutionary game is different from the traditional game method. It combines the evolutionary game idea and game theory. It is a dynamic game. In the current era of globalization, the economic problems caused by the competition of capital among countries form a complex system. The evolutionary game method can better analyze the whole process of the participants in the complex system changing with time, which has attracted widespread attention from scholars at home and abroad. Kang et al. [7] propose the stable strategy analysis based on the utility of Z-number in the evolutionary games, better to simulate the process of human competition and cooperation. Szolnoki et al. [8] review recent advances in related evolutionary games, focusing mainly on pattern formation, the impact of mobility, and the spontaneous emergence of cyclic dominance. Wang et al. [9] find a synergy between network science and evolutionary game theory. Promponas et al. [10], from the perspective of game theory, the study paradigm shift in the treatment of the uplink power control problem in wireless networks, introduce the concept of satisfaction equilibrium points and present a decentralized low complexity algorithm based on optimal response dynamics, prove that the only MSE point in the game is superior to other equilibrium points. Therefore, the evolutionary game can better analyze the whole process of the participants of debt restructuring along with time. This article introduces asset management companies as the fourth game subject and quantitatively analyzes the evolution process and strategic choices of the four subjects participating in debt restructuring.

The contributions of this article are as follows: First, from the perspective of game theory, the introduction of essential participants in debt restructuring asset management companies, and the establishment of a quartet evolutionary game model of debt restructuring with the participation of asset management companies. The evolutionary game method can better analyze the interaction mechanism of the four complex behavior and aims to deeply understand the internal mechanism of debt restructuring. Second, scholars in the past focused on studying debt restructuring from a macroscopic view, while this article studied the process of participating in debt restructuring from a microscopic view and provided a basis for successful debt restructuring by setting up a reasonable reward and punishment mechanism. Finally, using Matlab2018 software to analyze the impact of each essential element in the debt restructuring on the stability of the system evolution, the research results provide a basis for the successful debt restructuring of enterprises.

2. Problem Description and Model Building

2.1. Problem Description. When debt restructuring occurs, because of different interest demands of all parties, it is difficult for the government, enterprises, and banks to reach an agreement, which requires the participation of asset management companies with specific fund strength. When asset management companies participate in debt restructuring, it will change the balance of interests of other participants. The final purpose of the government is to help enterprises avoid bankruptcy liquidation to maintain socioeconomic solidarity; the final purpose of banks is to reduce their bad debt losses; the final purpose of enterprises is to reduce debt; and the final purpose of asset management companies is to maintain social stability while improving their interests. If the interest demands of all parties are satisfied, the interests of all parties cannot be balanced. At this time, all parties need to constantly adjust their interest demands through negotiations to balance the interests and finally realize debt restructuring. This article solves the following problems: (1) To successfully realize debt restructuring, what strategies should the government, banks, asset management companies, and enterprises adopt? (2) How do the two behaviors of enterprises working hard and not working hard affect the strategies of banks, asset management companies, and the government? (3) What impact does the strategic choice of banks and asset management companies have on the evolution of the strategies of each game player?

2.2. Research Hypothesis. The quartet game matrix of debt restructuring considering the participation of asset management companies is shown in Table 1.

In order to construct a game model for all the interests’ subject in debt restructuring and study the strategies of each debt restructuring subject under the participation of asset management companies, the hypotheses are as follows:

Hypothesis 1. The government, banks, asset management companies, and enterprises constitute the game subject of the debt restructuring. The strategies that the government can take to participate in debt restructuring are as follows: to give specific support and not to give specific support. The probability of the government giving specific support is x, and the probability of not giving specific support is 1−x; the strategies that banks can take to participate in debt restructuring are as follows: granting debt relief and participating in debt restructuring in the form of debt-to-equity swaps. The probability of banks giving the debt relief strategy is y, and the probability of the debt-to-equity swap strategy is 1−y; the strategies that asset management companies can take to participate in debt restructuring are as follows: acquisition of bad bank assets and providing liquidity. The probability of asset management companies acquiring bad bank assets is z, and the probability of asset management companies providing liquidity is 1−z; the strategies that enterprises can take to participate in debt restructuring are as follows: working hard and not working hard. The probability of enterprises working hard is k, and the probability of not working hard is 1−k, x, y, z, k∈[0,1]. The parties involved in debt restructuring are bounded rational, and constantly adjust their strategies to pursue maximize their respective interests with the evolution of time.
Hypothesis 2. The cost of the government giving specific support for debt restructuring is $C_1$, and the cost of not giving specific support for debt restructuring is 0; when the government does not provide specific support, the debt restructuring fails, and the enterprises are on the verge of bankruptcy, which will reduce government taxes and record it as $T_1$. The lack of government support for enterprises will increase the difficulty of restructuring. Enterprises lack motivation and choose not to work hard, causing debt restructuring to fail. The negative effects brought to the government are recorded as $N_1$ [11].

Hypothesis 3. Two strategies adopted by banks will have varying degrees of impact on the debt restructuring process [12]. (1) Debt relief strategy. The cost of debt relief is $C_2$. Compared with the debt-to-equity swap strategy, the debt relief strategy can motivate employees to work hard to repay the loan, but it can lead to a shortage of capital flow and failure to operate normally. The increase in enterprises’ risk costs are recorded as $E_1$, which increase the risk of enterprises’ bankruptcy and reduce government taxes, recorded as $H_1$ [13]. The government has a negative impression of banks’ failure to cooperate with debt restructuring. Increasing the banks’ local operating costs are recorded as $C_3$, but the banks use debt relief strategy to take back loans to offset the banks’ evaluation bad debt losses, and increase banks performance are recorded as $S_1$; (2) Debt-to-equity swap strategy. The debt-to-equity swap strategy can quickly reduce the enterprises’ debt ratio and accelerate the debt restructuring process. The government will have a positive impression of the bank, and the positive effect on the bank’s future operations is recorded as $B_2$. The banks choose the costs of debt-to-equity swap to be $C_4$, and the banks use the debt-to-equity swap strategy to improve the efficiency of disposing of bad assets and reduce the banks’ bad debt losses as $S_3$. Through this strategy, the enterprises reduce their liabilities. The enterprises work hard to avoid bankruptcy liquidation, thereby maintaining social stability, and increasing government tax revenue is recorded as $H_2$. When banks become enterprises’ shareholder, they will participate in the operation of enterprises, and the enterprises do not work hard—the additional burden on the banks are recorded as $J_1$.

Hypothesis 4. Asset management companies participate in debt restructuring with two strategies. (1) The strategy of acquiring bad bank assets. First, the asset management companies conduct debt negotiations with the banks, and the banks agree to grant debt relief. The amount of relief is recorded as $W_1$, and the debt is sold to the asset management companies at a certain discount. Among them, the asset management companies’ acquisition of debt fund costs is recorded as $C_5$, and the incomes are recorded as $S_4$. Thereafter, the asset management companies negotiated with the enterprises about the specific process of debt restructuring, and the enterprises’ debt principal relief is recorded as $D_1$. The behavior of asset management companies actively cooperating with debt restructuring will be affirmed by the government, and the positive effects on the future operations of asset management companies are recorded as $B_3$. When the asset management companies undertake the debt, if the enterprises do not work hard, the
burdens on the asset management companies are recorded as \( Q_i \). (2) The strategy of providing liquidity to the enterprises. The cost of funds provided to the enterprises is \( C_o \). After the enterprises get the funds, the income from hard work is recorded as \( G_i \). The enterprises refund the loans to the banks and reduce the banks’ bad debt losses as \( T_p \) which lighten social pressure. The increase in government tax is recorded as \( H_3 \), and the income from the liquidity provided by the asset management company is recorded as \( D_3 \). The behavior of asset management companies actively forcing debt restructuring will leave a good impression on the government, and its positive effects on local operations are recorded as \( B_4 \). After the asset management companies provide liquidity, if the enterprises do not work hard, it will bring negative benefits to the asset management companies and are recorded as \( R_1 \).

**Hypothesis 5.** Enterprises will choose to work hard for their own development considerations and the sense of social responsibility. The cost of hard work is \( C_2 \) and the cost of time is \( C_9 \). The government’s reward for actively cooperating with debt restructuring is recorded as \( M_1 \) (such as tax relief and tax-deferred etc.); the cost of enterprises not working hard is recorded as 0, and the government does not give any preferential policy to the enterprises that do not cooperate with debt restructuring. At the same time, the policy will increase the constrained force on the operation of the enterprises, and increasing the operating cost during the operation of the enterprises is recorded as \( L_5 \), so as to urge the enterprises to fulfill their social responsibility and choose the hard work strategy.

According to the above hypothesis, the payoff matrix of the quadrilateral evolutionary game of debt restructuring composed of the government, banks, asset management companies, and enterprises is shown in Table 1.

In the above payoff matrix, each party will continuously adjust its strategies to maximize the expected return. According to evolutionary game theory, when the return of a certain strategy is higher than the average return, this strategy will gradually evolve and develop. This process is called replicator dynamics equation, which is a dynamic differential equation that uses specific strategies in a system [14–16].

\[
\frac{dx}{dt} = x(U_{x1} - U_{x}).
\]

### 3. Strategy Stability Analysis of Each Game Subject

**3.1. Analysis of the Stability of Government Strategy.**

Expected revenue when the government chooses to give specific support strategy to debt restructuring enterprises:

\[
U_x = yzk(-C_1 - M_1 - H_1) + yz(1-k)(-C_1 - N_1 + L_5 - H_1) + y(1-z)(-C_1 - M_1 - H_1 + H_3) + y(1-z)(1-k)
\]

\[
\cdot (-C_1 - N_1 + L_5 - H_1 + H_3) + (1-y)zk(-C_1 - M_1 + H_2)
\]

\[
+ (1-y)z(1-k)(-C_1 - N_1 + L_3) + (1-y)(1-z)
\]

\[
\cdot k(-C_1 - M_1 + H_2 + H_3) + (1-y)(1-z)(1-k)(-C_1 - N_1 + L_5 + H_3).
\]

Expected revenue when the government chooses not to give specific support strategy to debt restructuring enterprises:

\[
U_{1-x} = yzk(-T_1) + yz(1-k)(-T_1 + L_3) + y(1-z)k(-T_1)
\]

\[
+ y(1-z)(1-k)(-T_1 + L_2) + (1-y)zk(-T_1)
\]

\[
+ (1-y)z(1-k)(-T_1 + L_4) + (1-y)(1-z)k(-T_1)
\]

\[
+ (1-y)(1-z)(1-k)(-T_1 + L_2).
\]

Assuming that the probability that the government chooses to give specific support to debt restructuring enterprises and not to give specific support to debt restructuring enterprises is \( x \) and \( 1-x \), respectively, the expected revenue of the government can be expressed as follows:
When Proposition 1, the probability of asset management selection cannot be determined through the size of \( x \) and \( F(x) \). Therefore, the \( F(x) \) and \( F'(x) \) conditions are analyzed through the size of \( z \) to analyze its strategy.

**Proposition 1.** When \( z < z_0 \), the government’s stable strategy is to give specific support; when \( z > z_0 \) the government’s stable strategy is to give no specific support. The threshold: \( z_0 = (1-y)kH_2+(1-k)N_1-kM_1-yH_1+T_1 \).

\[
V_1 = \frac{1}{H_3} \int_0^1 \left[ (1-y)kH_2 + (1-k)N_1 - kM_1 - yH_1 + T_1 \right] dxdz \\
= \frac{(H_1 + kH_2)(N_1 + T_1 - kM_1 - kN_1)}{2H_3^2} - \frac{1/2H_1 - N_1 - T - 1/2kH_2 + kM_1 + kN_1}{H_3} \\
- \frac{(N_1 + T_1 - kM_1 - kN_1)(N_1 + T_1 - kM_1 - kN_1 - kH_2)}{H_3^2} \\
V_2 = 1 - V_1.
\]
Corollary 1. The greater the negative benefit caused by the failure of debt restructuring as a result of the enterprises’ failure to work hard, the higher the probability that the government will give specific support, that is, the probability that the government chooses to give specific support is a positive correlation with the negative effect of the enterprises’ failure to work; when banks choose debt relief strategy, enterprises raise funds to return bank loans, reducing liquidity, increasing the difficulty of debt restructuring, affecting social stability, and reducing government taxes. At this time, the government should give specific support to debt restructuring enterprises to reduce losses, that is, the probability that the government chooses to give specific support to debt restructuring enterprises is a positive correlation with the reduction in government taxation caused by the banks’ choice of debt relief strategy; The government will give certain reward to enterprises (including tax relief and tax-deferred), but when the reward rate increases, in order to save costs, the probability of giving specific support strategy to the government will decrease, that is, the probability that the government chooses to give specific support is a negative correlation with the capital cost of the government rewarding the enterprises for hard work.

Proof. According to the expression of the probability $V_1$ of the government giving specific support to the debt restructuring enterprise, find the first-order partial derivative of each element, and gets: $\frac{\partial V_1}{\partial C_1} \langle 0$, $\frac{\partial V_1}{\partial M_1} \langle 0$, $\frac{\partial V_1}{\partial H_1} \langle 0$. Therefore, the increase in $N_1$ and $H_1$ or the decrease in $C_1$ and $M_1$ can increase the probability that the government chooses to give specific support to debt restructuring enterprises.

It shows that in the process of debt restructuring, if the enterprise does not work hard, it will bring negative benefits to the government. When the negative benefits increase, it will not only lead to the bankruptcy of the debt enterprise and the failure of debt restructuring, but also affect the stability of society. At this time, the government needs to play a supporting role to maintain social stability and maximize social welfare. If the enterprises are on the verge of bankruptcy, the government will have little impact on taxation and socioeconomic, and the government will choose not to give specific support strategy in order to save support costs.

3.2. Analysis of the Stability of Banks’ Strategy. Expected revenue when the banks choose to give enterprises debt relief strategy is as follows:

$$U_y = xzk(-C_2 + S_2 - C_3 - W_1) + xz(1-k)(-C_2 - C_3 - W_1) + x(1-z)k(-C_2 + S_2 - C_3 + T_4) + x(1-z)(1-k)(-C_2 - C_3 + T_4) + (1-x)zk(-C_2 + S_3 - W_1) + (1-x)z(1-k)(-C_2 - W_1) + (1-x)(1-z)k(-C_2 + S_2 + T_4) + (1-x)(1-z)(1-k)(-C_2 + T_4).$$

(7)

Expected revenue when the banks choose debt-to-equity swap strategy is as follows:

$$U_{1-y} = xzk(S_3 + B_2 - C_4) + xz(1-k)(S_4 + B_2 - C_4 - J_1) + x(1-z)k(S_3 + B_2 - C_4 + T_4) + x(1-z)(S_4 + B_2 - C_4 + T_4 - J_1) + (1-x)zk(S_3 - C_4) + (1-x)z(1-k)(S_3 - C_4) + (1-x)k(1-z)(S_3 - C_4 + T_4).$$

(8)
Assuming that the probability that the banks choose to give enterprises debt relief and debt-to-equity swap strategy is \( y \) and \( 1-y \), respectively, the expected revenue of the banks can be expressed as follows:

\[
F(y) = \frac{d y}{d t} = y(1-y)(U_y - U_{1-y}) = y(1-y)(C_4 - C_2 - S_3 - xB_2 - xC_3 + kS_2 + xJ_1 - zW_1 - xkJ_1),
\]

Proposition 2. When \( x < x_0 \), the banks’ stable strategy is to give enterprises debt relief; when \( x > x_0 \), the banks’ stable strategy is debt-to-equity swap. The threshold: \( x = (-C_4+C_2+S_3-kS_2+zW_1)/(B_2+C_3)\cdot kJ_1)^{1/2} = x_o \). 

Proof. \( H(x) = C_4-C_2-S_3-xB_2-xC_3+kS_2+xJ_1\cdot zW_1\cdot xkJ_1 \), \( \partial H(x)/\partial x(0) < 0 \), \( H(x) \) is a decreasing function of \( x \), when \( x < x_0 \), \( H(x) > 0 \), \( F(y)|y = 1 = 0 \), and \( F'(y)|y = 1 < 0 \), at this time \( y = 1 \) is stable; when \( x > x_0 \), \( H(x) < 0 \), \( F(y)|y = 0 = 0 \), and \( F'(y)|y = 0 < 0 \), at this time \( y = 0 \) is stable; and when \( x = x_0 \), \( H(x) = 0 \), \( F(y) = 0 \), and \( F'(y) = 0 \), at this time, the banks’ strategy selection cannot be determined.

Proposition 2 shows that in the process of debt restructuring, as the probability of the government giving specific support increases, the banks’ stable strategy has changed from giving enterprises debt relief strategy to the debt-to-equity swap strategy; similarly, as the probability of government chooses not to give specific support strategy increases, the banks’ strategy will change from the debt-to-equity swap strategy to the debt relief strategy. This shows that under the specific support of the government, the probability of enterprises operating capacity will increase. Banks can obtain policy support. When the banks choose the debt-to-equity swap strategy, it converts the banks’ debt to equity to reduce the banks’ bad debt losses and obtain greater profit margins. At this time, the banks’ stable strategy is the debt-to-equity swap strategy; on the contrary, if the probability of the government not giving specific support increases, at the same time, the expectation of enterprises to improve their operating capabilities is uncertain, considering the interests, they prefer more to choose the debt relief strategy, thereby reducing future risks. According to Proposition 2, the banks’ strategy selection phase diagram is shown in Figure 2.

In Figure 2, the volume of part \( V_3 \) represents the probability that the banks choose debt relief, and the volume of part \( V_4 \) represents the probability that the banks choose debt-to-equity swap strategy, which can be obtained by as follows:

\[
\begin{align*}
V_3 &= \int_0^1 \frac{C_4 + C_2 + S_3 - S_2 + zW_1}{B_2 + C_3} \int_0^{1-(C_4 + C_2 + S_3 - kS_2 + zW_1)/(B_2 + C_3)} \frac{C_4 + C_2 + S_3 - kS_2 + zW_1}{B_2 + C_3 - J_1} dy dx \\
V_4 &= 1 - V_3.
\end{align*}
\]
to choose debt relief strategy. That is, the probability of banks choosing debt relief is a positive correlation with the operating burden of choosing debt-to-equity swap strategy; banks choose debt-to-equity swap strategy to improve the efficiency of disposing of bad asset and reduce bank losses on bad debts. The greater the reduction in losses, the greater the probability that banks will choose debt-to-equity swap strategy, and the lower the probability that they will choose debt relief strategy, that is, the probability that the banks choose to give enterprises debt relief is a negative correlation with the banks’ bad debt loss.

Proof. According to the expression of the probability \( V_3 \) that the banks choose to give debt relief to the enterprises, find the first-order partial derivative of each element, and get: \( \partial V_3/\partial S_2 \neq 0, \partial V_3/\partial C_4 \neq 0, \partial V_3/\partial f_1 \neq 0, \partial V_3/\partial C_2 \neq 0, \partial V_3/\partial C_4 \neq 0, \partial V_3/\partial S_1 \neq 0 \). Therefore, the increase in \( S_2, C_4 \), and \( f_1 \) or the decrease in \( C_2, C_4, \) and \( S_2 \) can increase the probability that banks choose to give debt relief to debt enterprises.

It shows that in the process of debt restructuring, banks choose the debt-to-equity swap strategy, which reduce bank bad debt losses. At the same time, banks become one of the shareholders of enterprises. They should participate in the operation of the enterprise and plan the future development of the enterprises, which increase the banks’ operating risks. Compared with the debt-to-equity swap strategy, the banks choice of debt relief strategy can enable them to avoid risks while reducing banks’ bad debt losses, at this time, banks are more willing to choose debt relief strategy. However, this strategy will increase the difficulty of debt restructuring and affect the debt restructuring process. This behavior of the banks will bring a negative impression to the government, increase the banks’ future operating costs, and choose the debt-to-equity swap strategy, which can effectively improve the efficiency of the banks’ bad assets processing. At this time, the bank will choose the debt-to-equity swap strategy.

3.3. Analysis of the Stability of Asset Management Companies’ Strategy. Expected revenue when asset management companies choose the strategy for acquiring bad assets is as follows:

\[
U_Z = xyk(-C_5 + S_4 + B_3) + xy(1 - k)(-C_5 + S_4 + B_3 - Q_t) + xk(1 - y)(-C_5 + S_4 + B_3) \\
+ x(1 - y)(1 - k)(-C_5 + S_4 + B_3) + yk(1 - x)(-C_5 + S_4) + y(1 - x)(1 - k)(-C_5 + S_4 - Q_t) \\
+ k(1 - x)(1 - y)(-C_5 + S_4) + (1 - x)(1 - y)(1 - k)(-C_5 + S_4).
\]

Expected revenue when asset management companies choose the strategy for providing liquidity is as follows:

\[
U_{1-Z} = xyk(-C_6 + D_2 + B_4) + xy(1 - k)(-C_6 + D_2 + B_4 - R_1) + xk(1 - y)(-C_6 + D_2 + B_4) \\
+ x(1 - y)(1 - k)(-C_6 + D_2 + B_4 - R_1) + yk(1 - x)(-C_6 + D_2) + y(1 - x)(1 - k)(-C_6 + D_2 - R_1) \\
+ k(1 - x)(1 - y)(-C_6 + D_2) + (1 - x)(1 - y)(1 - k)(-C_6 + D_2 - R_1).
\]
Assuming that the probability that the asset management companies choose to acquire bad assets and provide liquidity is \( z \) and \( 1-z \), respectively, the expected revenue of the asset management companies can be expressed as follows:

\[
\mathbb{E} = z U_z + (1-z) U_{1-z}.
\]

The asset management companies’ replication dynamic equation can be calculated as follows:

\[
F(z) = \frac{dz}{dt} = z(U_z - \mathbb{E}) = z(1-z)(U_z - U_{1-z}) = z(1-z)(C_5 - C_3 - D_2 - Q_1 + S_4 + xB_3 - xB_4 - kR_1 - yQ_1).
\]

**Proposition 3.** When \( k < k_0 \), the asset management companies’ stable strategy is to acquire bad assets; when \( k > k_0 \), the asset management companies’ strategy selection is related to the size of the enterprises’ strategy selection probability \( k \). Therefore, the \( F(z) \) and \( F'(z) \) conditions are analyzed through the size of \( k \) to analyze its strategy.

According to the stability theorem of differential equations, the asset management companies’ choice of acquiring banks’ bad assets can be obtained as follows:

**Proof.** \( H(k) = (R_1 - yQ_1) + (C_5 - C_3 - D_2 - Q_1 + S_4 + xB_3 - xB_4) \), \( \partial H(k)/\partial k \) is a decreasing function of \( k \), when \( k < k_0 \), \( H(k) > 0 \), \( F(z)|_{z=1} = 0 \), and \( F'(z)|_{z=1} < 0 \), at this time \( z = 0 \) is stable; when \( k > k_0 \), \( H(k) < 0 \), \( F(z)|_{z=0} = 0 \), and \( F'(z)|_{z=0} < 0 \), at this time \( z = 0 \) is stable; and when \( k = k_0 \), \( H(k) = 0 \), \( F(z) = 0 \), and \( F'(z) = 0 \), at this time, the asset management companies’ strategy selection cannot be determined.

Proposition 3 shows that in the process of debt restructuring, as the probability of enterprises working hard increases, the strategy of asset management companies has changed from providing liquidity to acquiring banks’ bad assets to providing liquidity to enterprises. At the same time, as the probability of enterprises not working hard increase, the strategy of asset management companies has changed from providing liquidity to acquiring bad bank assets. The hard work of enterprises has released a positive signal to asset management companies, that is asset management companies are more willing to provide liquidity to help enterprises relieve financial pressure and avoid enterprises’ bankruptcy. At this time, the asset management companies’ stable strategy is to provide liquidity; on the contrary, if the enterprises do not work hard, when the asset management companies provide funds to the enterprises, the asset management companies cannot recover the funds on time. In order to reduce this risk, the asset management companies will choose the strategy of acquiring banks’ bad assets. After acquiring banks’ bad assets, the acquired bad assets can be sold externally. Compared with the strategy of providing liquidity, choosing the strategy of acquiring banks’ bad assets can better avoid risks.

According to Proposition 3, the phase diagram of the asset management companies’ strategy choice of debt restructuring is shown in Figure 3.

In Figure 3, the volume of part \( V_5 \) represents the probability that the asset management companies choose to acquire bad assets, and the volume of part \( V_6 \) represents the probability that the asset management companies choose to provide liquidity, which can be obtained as follows:

\[
V_5 = \frac{(C_5 - C_6 + D_2 + Q_1 - S_4 + R_1 - yQ_1)}{R_1 - yQ_1} \int_0^1 \frac{(C_5 - C_6 + D_2 + Q_1 - S_4 - xB_3 + xB_4 - R_1 - yQ_1)}{R_1 - yQ_1} \, dk
\]

\[
V_6 = 1 - V_5.
\]
Corollary 3. The behavior of asset management companies choosing to acquire banks’ bad assets will be affirmed by the government, and the greater the positive effect it will have on the asset management companies’ future operations, the higher the probability that asset management companies will choose to acquire banks’ bad assets, that is, the probability that the asset management companies choose to acquire the bank’s bad assets is positively correlated with the positive effect that the government provides to the asset management companies in the future. After the asset management companies provide liquidity to the enterprises, the enterprises cannot repay the loan without working hard, hence it will bring negative benefits to the asset management companies. If the asset management companies do not work hard after taking on bank debts, it will bring a burden to the asset management companies. The greater the burden, the lower the probability that the asset management companies will choose to acquire banks’ bad assets, that is, the probability that asset management companies’ choice to acquire banks’ bad assets is negatively correlated with the burden of asset management companies acquiring bad assets.

Proof. According to the expression of the probability \( V_5 \) that the asset management companies choose to acquire banks’ bad assets, find the first-order partial derivative of each element, and get:

\[
\begin{align*}
\frac{\partial V_5}{\partial S_5} & \geq 0, \quad \frac{\partial V_5}{\partial B_5} \geq 0, \quad \frac{\partial V_5}{\partial R_5} \geq 0, \quad \frac{\partial V_5}{\partial C_5} \leq 0, \quad \frac{\partial V_5}{\partial C_5} \leq 0, \quad \frac{\partial V_5}{\partial D_5} \leq 0, \quad \frac{\partial V_5}{\partial B_5} \leq 0, \quad \frac{\partial V_5}{\partial Q_5} \leq 0. \\
\end{align*}
\]

Therefore, the increase in \( S_5, B_5, R_5, \) and \( C_5 \) or the decrease in \( C_5, D_5, B_5, \) and \( Q_5 \) can increase the probability that asset management companies choose to acquire banks’ bad assets. It shows that: In the process of debt restructuring, as asset management companies choose to acquire banks’ bad assets and gain increase, asset management companies will naturally choose to acquire banks’ bad assets. The magnitude of the positive effect that the government has on the local operations of the asset management companies can affect the strategic choice of the asset management companies. When banks are eager to reduce bad debt losses, they will give more preferential treatment to asset management companies, and the acquisition cost of asset management companies will be reduced. At this time, asset management companies will be more inclined to choose the strategy of acquiring banks’ bad assets.

\[ \Box \]

3.4. Analysis of the Stability of Enterprises’ Strategy. Expected revenue when enterprises choose the strategy for working hard is as follows:

\[
U_k = xyz(D_1 - C_7 - C_8 + M_1) + xy(1 - z)(G_1 - C_7 - C_8 + M_1) + xz(1 - y)(D_1 - C_7 - C_8 + M_1)
\]

\[
+ x(1 - y)(1 - z)(-C_7 - C_8 + M_1 + G_1) + z(1 - x)(1 - y)(D_1 - C_7 - C_8) + (1 - x)(1 - y)(1 - z)(-C_7 - C_8 + G_1)
\]

(17)

Expected revenue when enterprises choose the strategy for not working hard is as follows:

\[
U_{1-k} = xyz(D_1 - L_5 - E_1) + xy(1 - z)(-E_1 - L_5) + xz(1 - y)(D_1 - L_5) + x(1 - y)(1 - z)(-L_5)
\]

\[
+ yz(1 - x)(D_1 - L_5 - E_1) + y(1 - x)(1 - z)(-E_1 - L_5) + z(1 - x)(1 - y)(D_1 - L_5) + (1 - x)(1 - y)(1 - z)(-L_5).
\]

(18)

Assuming that the probability that the enterprises choose to work hard and not to work hard is \( k \) and \( 1-k \), respectively, the expected revenue of the enterprises can be expressed as follows:

\[
U_k = \frac{1}{2}U_{1-k} + \frac{1}{2}U_{1-k}.
\]

\[
U_{1-k} = \frac{1}{2}U_k + \frac{1}{2}U_k.
\]
The enterprises’ replication dynamic equation can be calculated as follows:

\[ \mathcal{U} = kU_k + (1 - k)U_{1-k}. \]  

(19)

\[
F(k) = \frac{dk}{dt} = k(U_k - \mathcal{U}) = k(1 - k)(U_k - U_{1-k}) = k(1 - k)(G_1 - C_7 - C_8 + L_5 - yE_1 - zG_1 + xM_1 + 2yzE_1),
\]

(20)

According to the stability theorem of differential equations, the enterprises’ strategy selection probability of achieving a stable state must meet the following two conditions: \( F(k) = 0 \) and \( F'(k) < 0 \). The enterprises’ strategy selection is related to the size of the government’s strategy selection conditions. Therefore, the \( F(k) \) and \( F'(k) \) conditions are analyzed through the size of \( k \) to analyze its strategy.

**Proposition 4.** When \( x > x_0 \), the enterprises’ stable strategy is to work hard; when \( x < x_0 \), the enterprises’ stable strategy is not to work hard. The threshold: \( x = (C_7 + C_8 - G_1 - L_5 + yE_1 + zG_1 - 2yzE_1) \cdot M_1^{-1} = x_0 \).

**Proof.** \( H(x') = G_1 - C_7 - C_8 + L_5 - yE_1 - zG_1 + xM_1 + 2yzE_1, \partial H(x')/\partial x > 0, \) \( H(x') \) is an increasing function of \( x \), when \( x > x_0 \), \( H(x') > 0, F(k)|_{k=1} = 0, \) and \( F(k)|_{k=0} < 0, \) at this time \( k = 1 \) is stable; when \( x < x_0 \), \( H(x') < 0, F(k)|_{k=0} < 0, \) at this time \( k = 0 \) is stable; and when \( x = x_0 \), \( H(x') = 0, F(k) = 0, \) and \( F'(k) = 0, \) at this time, the enterprises’ strategy selection cannot be determined.

Proposition 4 shows that in the process of debt restructuring, with the increase of the probability that the government chooses to give a specific support strategy, the strategy of enterprises will change from not working hard to working hard. As the probability that the government chooses not to give specific support increases, the enterprises’ strategy will change from working hard to not working hard. It can be seen that the government’s specific support strategy plays a positive role in the debt restructuring process. The government’s specific support strategy promotes the debt restructuring process. Enterprises are more willing to work hard to improve their operational capabilities. At this time, enterprises’ stable strategy is hard work; on the contrary, if the government chooses not to give specific support to enterprises, it will increase the difficulty of debt restructuring, and enterprises will choose not to work hard.

According to Proposition 4, the phase diagram of the enterprises’ strategy choice of debt restructuring is shown in Figure 4.

In Figure 4, the volume of part \( V_7 \) represents the probability that the enterprises choose to work hard, and the volume of part \( V_8 \) represents the probability that the enterprises choose not to work hard, which can be obtained as follows:

\[
V_7 = \int_{-\infty}^{\infty} \frac{C_7 + C_8 - G_1 - L_5 + yE_1}{M_1} \, dk, \quad V_8 = 1 - V_7.
\]

(21)

**Corollary 4.** When enterprises do not work hard, the government will not give any preferential policies to them that do not cooperate with debt restructuring, and will increase restrictions on enterprises’ operations, increase enterprises’ operating costs, and urge enterprises to fulfill their social responsibilities. The greater the restriction and the higher the operating cost, the enterprises will choose hard work strategy, that is, the probability that the enterprises choose hard work strategy is
positively correlated with the enterprises get the operating income; banks’ debt relief strategy will stimulate enterprises working hard to repay loans, but this behavior will reduce the enterprises’ liquidity, increase the difficulty of debt restructuring, and increase business risks. The greater the risk, the less likely the enterprises will choose the hard work strategy. The probability that enterprises choose to work hard is negatively correlated with the operating risk that the banks bring to the enterprises after the banks choose the debt relief.

Proof. According to the expression of the probability \( V_7 \) that the enterprises choose to work hard, find the first-order partial derivative of each element, and get: \( \partial V_7/\partial M_1 > 0, \partial V_7/\partial L_0 > 0, \partial V_7/\partial G_1 = 0, \partial V_7/\partial C_7 = 0, \partial V_7/\partial E_1 = 0 \). Therefore, the increase in \( M_1, L_0 \), and \( G_1 \), or the decrease in \( C_7 \) and \( E_1 \) can increase the probability that enterprises choose to work hard.

It shows that when enterprises work hard, it can help them successfully tide over the debt crisis and obtain higher benefits. If the enterprises do not work hard, it will not only affect their own development, but also harm the stability of society, resulting in a reduction in government tax revenue. The government will not give any preferential policies to enterprises that do not cooperate with debt restructuring and will increase the degree of restraint on corporate operations, increase operating costs in the process of corporate operations, and urge them to fulfill their social responsibilities, and choose hard work strategy. Enterprises will pay costs for hard work. When the cost of hard work is too high, it will also cause some enterprises to choose not to work hard for the immediate benefit, regardless of their own long-term development. Therefore, when the government formulates measures, it must also favor certain policies of debt restructuring enterprises and parties that cooperate with debt restructuring.

4. Stability Analysis of Strategy Combination

In the replicated dynamic system of the quartet evolutionary game of governments, banks, asset management companies, and enterprises, the stability of the strategic combination of each participant can be judged according to the first rule of Lyapunov: when the size of each eigenvalue in the Jacobian matrix is less than 0, each equilibrium point is a system stable evolution strategy; when the size of each eigenvalue in the Jacobian matrix is greater than 0, each equilibrium point is an unstable point at this time; when the eigenvalues in the Jacobian matrix are all less than 0 except 0, the equilibrium points are in a critical state and the stability is uncertain. Related scholars pointed out that the stable solution in the evolutionary game system must be a strict Nash equilibrium solution [18–22]. Therefore, in the quartet evolutionary game of debt restructuring, this article will analyze the stability of the equilibrium point of the debt restructuring system with 16 pure strategies.

According to the replication dynamic equation of each participant, the Jacobian matrix of the replication dynamic system can be obtained as follows:

\[
J = \begin{bmatrix}
\frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} & \frac{\partial F(x)}{\partial k} \\
\frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} & \frac{\partial F(y)}{\partial k} \\
\frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} & \frac{\partial F(z)}{\partial k} \\
\frac{\partial F(k)}{\partial x} & \frac{\partial F(k)}{\partial y} & \frac{\partial F(k)}{\partial z} & \frac{\partial F(k)}{\partial k}
\end{bmatrix}
\]  

(22)

4.1 Analysis on the Stability of Strategic Portfolio under the Hard Work of Enterprises. The stability strategy of debt companies is hard work; the condition \( G1-C7-C8+L5-2yE1-zG1+xM1+2yzE1 > 0 \) is satisfied; and \( F(x) = 0, F(y) = 0, F(z) = 0 \), and \( F(k) = 0 \) can obtain the stable equilibrium point of the quartet evolutionary game. The analysis of the stable point of the equilibrium point of the replicated dynamic system is shown in Table 2.

It can be seen from Table 2 that there are two possible stabilization strategies \( (1, 0, 0, 1) \) and \( (1, 1, 0, 1) \) under the efforts of enterprises. Among them, \( (1, 0, 0, 1) \) indicates that the government gives specific support to enterprises to maintain social stability, banks choose debt-to-equity swap strategy to reduce bad debt losses, asset management companies choose to provide liquidity to avoid risks while gaining profits, and enterprises choose to work hard for their own development and social responsibility.
Through further research, it is found that $(1, 0, 0, 1)$ need to meet the conditions: $B_4-D_2 > B_3-C_5+C_6+S_4$, which shows that asset management companies actively promote debt restructuring and leave a good impression on the government. The greater the positive effect on its local operations, the higher the probability that the asset management companies will choose to provide liquidity to the enterprises, and at the same time, it will increase the income of the asset management companies’ choice of providing liquidity to the enterprises so that $B_4-D_2 > B_3-C_5+C_6+S_4$. Condition is established. When this condition is met, the asset management companies’ stable strategy is to provide liquidity to the enterprise. At this time, the strategic equilibrium point of $(1, 0, 0, 1)$ is the stable point.

When the government’s rewards for working hard to cooperate with debt restructuring companies do not increase, the stability point of the replication dynamic system will deviate, and the stability point will deviate from the optimal state at this time $(1, 0, 0, 0)$, when the condition $M_1 < H_3+T_1-C_1-H_1$ is met, the replication dynamic system will be stable at $(1, 1, 0, 1)$. At this time, the stability strategy of the replication dynamic system is the government’s debt restructuring enterprise-specific support, banks choose to grant corporate debt relief, asset management companies choose to provide liquidity to companies, and companies choose to work hard. Obviously, this approach will increase the difficulty of debt restructuring, affect the process of debt restructuring, increase the probability of corporate bankruptcy, and reduce social stability, thus reducing social welfare.

Therefore, it is necessary to prevent $(1, 1, 0, 0)$ from becoming a stable point of the replication dynamic system. It can be seen that the government should increase the rewards for hard-working enterprises to meet this condition: $M_1 > H_3+T_1-C_1-H_1$, keeping the stable point of the replication dynamic system $(1, 0, 0, 1)$, which can complete high-quality debt restructuring and maximize social welfare.

### 4.3. Theoretical Analysis of the Computational Complexity

According to the computational complexity method proposed by Promponas et al. [10], this paper makes a theoretical analysis of the proposed evolutionary game model of debt restructuring. Under the premise that the game is played in sequence in the given order of the selected subjects, the worst case of the algorithm is used to analyze the complexity. From the perspective of a single agent $k$, analyze the time complexity of its CPU, since the evolutionary game framework is implemented in a den- dritic framework, the time it takes for other agents to respond needs to be excluded and each agent needs to respond accordingly in a single cycle. The worst case depends on the cycle of turns of the game $C = |U_1|+\cdots+|U_k|$, therefore, in the game cycle of $C-|U_k|$, the agent $k$ will find a satisfactory point in constant time. In addition, in
Table 3: Analysis of the gradual stability of the equilibrium point of the replication dynamic system without hard work of the enterprises.

<table>
<thead>
<tr>
<th>Point of equilibrium</th>
<th>Eigenvalue</th>
<th>Sign</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1, 1, 1, 0)</td>
<td>C1+H1+N1-T1, B2+C2+C3–C4+J1+S3+W1, B4–B3+C5–C6+D2+Q1-R1+S4, L5-C8-C7+M1</td>
<td>( - - \ + )</td>
<td>ESS when (3) is satisfied</td>
</tr>
<tr>
<td>(1, 1, 0, 0)</td>
<td>C1+H1–H3+N1–T1, B2+C2+C3–C4+J1+S3, B3–B4–C5+C6–D2–Q1+R1+S4, G1-C8-C7–E1–C7+L5+M1</td>
<td>( - - \ + )</td>
<td>×</td>
</tr>
<tr>
<td>(1, 0, 0, 0)</td>
<td>C1–H3+N1–T1, C4–C2–C3–B2+J1+S3, B3–B4–C5+C6–D2+R1+S4, G1–C7-C8+L5+M1</td>
<td>( - - + - )</td>
<td>Unstable</td>
</tr>
<tr>
<td>(1, 0, 1, 0)</td>
<td>C1+N1–T1, C4–C2–C3–B2+J1+S3–W1, B4–B3+C5–C6+D2–R1+R1+S4, L5–C7+C8+M1</td>
<td>( - - + - )</td>
<td>Unstable</td>
</tr>
<tr>
<td>(0, 1, 1, 0)</td>
<td>T1–H1–N1–C1, C2–C4+S3+W1, C5–C6+D2–Q1+R1+S4, L5–C7–C8</td>
<td>( - - \ + )</td>
<td>Unstable</td>
</tr>
<tr>
<td>(0, 1, 0, 0)</td>
<td>H3–H1–C1–N1+T1, C2–C4+S3, C6–C5–D2–Q1+R1+S4, -C8+L5–C7</td>
<td>( - - \ + )</td>
<td>Unstable</td>
</tr>
<tr>
<td>(0, 0, 1, 0)</td>
<td>T1–N1–C1, C4–C2–S3–W1, -C5+C6–D2–Q1+R1+S4, G1–C8–2E1–C7+L5</td>
<td>( - + + )</td>
<td>×</td>
</tr>
<tr>
<td>(0, 0, 0, 0)</td>
<td>H3–C1–N1+T1, C4–C2–S3, C6–C5–D2–Q1+R1+S4, G1–C8–C7+L5</td>
<td>( - + + )</td>
<td>×</td>
</tr>
</tbody>
</table>

Note. \ means that the positive and negative are uncertain; × means that the condition is not met; ESS means the evolutionary stability strategy; if condition (3) is not met, it is an unstable point. Condition (3) B4–B3+C5–C6+D2+Q1–R1–S4 < 0.

Figure 5: The impact of government support costs on the evolution of various parties’ strategies.
the $|U_k|$ cycle of turns, the agent $k$ runs the modified binary search to get the current extreme value, then performs a binary search based on the results to find the next strategy. So over the full cycle, $O((C-|U_k|)+2|U_k|\log2|U_k|)$ will be required, and the total time complexity is $O((C-|U_k|)+|U_k|\log2|U_k|))$.

5. Simulation Analysis

5.1. Initial Parameter Setting. In order to more intuitively show the influence of various elements in the debt restructuring system on the evolution of the system, this article analyzes the case of enterprises that have undergone debt restructuring, taking Sanpower Groups as an example. Sanpower Group is a large-scale modern enterprise group characterized by informatization. Due to the sluggish global business environment and the enterprise’s poor management, in June 2018, Sanpower Group’s capital chain broke and fell into a debt crisis. In December 2018, the financial creditors of Sanpower Group held a meeting to determine the debt restructuring plan. The restructuring plan entirely took into account the interests of all parties and obtained the support of the government. At the same time, the asset management company actively intervened as the debt receiver. Through debt restructuring, Sanpower Group was able to revitalize its operating cash flow and gradually repair related assets, the main business can be operated normally, the enterprise can return to the regular development track, and the stability of debt repayment assets and cash flow is guaranteed. With the joint efforts of the government, banks, asset management companies, and the enterprise itself, Sanpower Group has implemented debt restructuring in a market-oriented and legalized manner, exploring an efficient and feasible new path for companies caught in debt crisis to get out of their predicaments and resolve their debts. The case of Sanpower Group’s debt restructuring provides comprehensive, detailed, and authoritative case data for this study.

*Figure 6: The influence of the strength of government rewards and constraint strength on the evolution of strategies of all parties.*
Referring to the practices of Xu et al. [14], Chen et al. [15], Tian et al. [17], and Wang et al. [21], combined with the actual situation of the relevant debt restructuring enterprises, the values of other parameters are drawn up, this article sets the government provides specific support cost for enterprises as $C_1 = 2$, increase tax revenue as $H_2 = 2$; government losses without specific support as $T_1 = 7$, and the negative effects to the government as $N_1 = 6$, and banks choose debt relief costs as $C_2 = 7$, and improving bank performance as $S_2 = 4$. The enterprises increased risk cost as $E_1 = 5$, and the government’s tax reduction as $H_1 = 3$. The increased operating cost of the bank as $C_3 = 2$. The banks choose the cost of debt-to-equity swap to be $C_4 = 2$, the banks reduced bad debt loss as $S_3 = 3$, the increased government tax as $H_2 = 2$, and the positive government effect on bank operations as $B_2 = 2$. The additional burden generated by the bank is $J_1 = 4$. The loan amount given by the banks as $W_1 = 4$, the capital costs of the asset management companies’ acquisition as $C_5 = 4$, the income as $S_4 = 4$, the debt relief that the enterprises will get as $D_1 = 2$, and the government’s positive effect on the asset management companies’ operation as $B_3 = 2$ brings a burden to the asset management companies as $Q_1 = 3$. The cost of an asset management company’s liquidity provision as $C_6 = 3$, the income as $G_1 = 3$, the reduced banks’ financial risk cost as $T_4 = 4$, and the increased government tax as $H_3 = 3$. The income from the asset management company providing liquidity as $D_2 = 5$. The government has a positive effect on the local operation of the asset management companies as $B_4 = 5$. Enterprises do not strive to bring negative benefits to asset management companies as $R_1 = 5$. The costs of hard work for enterprises as $C_7 = 8$, and the costs of time as $C_8 = 10$. The government rewards companies for actively cooperating with debt restructuring as $M_1 = 9$, and the government increases the operating costs of enterprises as $L_5 = 8$.

The initial strategy choices of each player are as follows: $x = 0.4$, $y = 0.2$, $z = 0.3$, and $k = 0.5$. The above parameters and replicator dynamic equation are written into the Matlab2018 program for simulation.

**Figure 7:** The impact of the cost of hard work on the evolution of each party’s strategy.
5.2. The Impact of Government Support Costs. Suppose $C_1 = \{2, 4, 6\}$, the primary strategy evolution process of the quartet evolutionary game is shown in Figure 5.

It can be seen from Figure 5 that the size of the specific support cost given by the government will affect the strategy evolution trend in the other three parties, which has a greater impact on the strategy evolution trend in the enterprises. As the cost of the government to give specific support increases, the probability that the government chooses not to give specific support will increase. The enterprises will choose not to work hard because the government does not give specific support, and the longer it takes to stabilize the strategy of not working hard, therefore, by reducing the cost of specific government support, it can encourage enterprises to choose hard work strategy.

5.3. The Impact of Government Rewards and Constraint Strength on the Evolutionary Results. Suppose $M_1 = \{6, 12, 25\}$ and $L_5 = \{8, 14, 30\}$, the primary strategy evolution process of the quartet evolutionary game is shown in Figure 6.

It can be seen from Figure 6 that the government increases its rewards and punishments for enterprises, the probability that enterprises choose to work hard and asset management companies choose to acquire bad assets of banks will gradually increase, and it will remain stable with this strategy. At the same time, the probability of banks choosing debt relief and the government’s specific support is gradually decreasing, and finally stabilized at 0, and the probability of asset management companies choosing to acquire bad assets of banks stabilized at 1.

5.4. The Impact of Enterprises’ Hard Work Cost on the Evolution Result. Suppose $C_7 = \{12, 8, 6\}$ and $C_8 = \{24, 10, 8\}$, the primary strategy evolution process of the quartet evolutionary game is shown in Figure 7.

It can be seen from Figure 7 that as the cost of hard work for enterprises decreases, the enterprises will gradually choose to work hard, and eventually stabilize on the hard work strategy; at this time, the government can reduce the intensity of specific support and save support costs. It can be seen that reducing enterprises’ costs by improving enterprises’ technology and reducing losses in the operation process can effectively increase the probability of enterprises working hard, thereby maintaining social welfare.

5.5. The Influence of the Government’s Specific Support Mechanism on the Evolution Result. In order to further verify the influence of the government’s specific support level on the evolution of strategies of banks, asset management companies, and enterprises in the process of debt restructuring, we set $x = 0$ and $x = 0.9$ to indicate that the government does not give specific support and gives specific support, respectively. In the three-dimensional space to simulate the evolution of the three-party strategy choices of banks, asset management companies, and enterprises, the simulation results are shown in Figure 8.

It can be seen from Figure 8 that when $x = 0$, that is, when the government does not give specific support, the enterprise stabilization strategy is not unique, and the banks’ strategic choice basically leans towards debt relief strategy; When $x = 0.9$, that is, when the government provides specific support, there is no stable point in the debt restructuring system at this time. However, if the government’s strategy is to maintain the probability of giving specific support at a certain level, the probability of the enterprises choosing to work hard will be greatly increased, and it is basically stable in the state of hard work. At this time, the banks will choose the debt-to-equity swap strategy. This is consistent with the results of the previous analysis of the system stability of the strategy portfolio under the specific support strategy given by the government.

6. Conclusion

This article uses evolutionary game theory to construct a quartet evolutionary game model with the participation of asset management companies, analyzes the interaction mechanism of the complex behaviors of the game players, analyzes the stability of each game player’s strategy, and find a stable point that maximizes the interests of each participant, using Matlab2018 simulation to analyze the impact of each key element on the evolution and stability of the system.
The results show that: (1) When the government chooses to give the specific support strategy, banks choose debt-to-equity swap strategy, asset management companies choose to provide liquidity strategy, and enterprises choose hard work strategy, the replication dynamic system will reach a stable state. (2) With the increase in the probability of the government choosing to give the specific support strategy, the banks’ strategy has changed from debt relief to debt-to-equity swaps, and the enterprises’ strategy has changed from not working hard to hard working. (3) With the increase in the probability of enterprises working hard, the strategy of asset management companies has changed from acquiring bad bank assets to providing liquidity. (4) The government’s specific support strategy has played an active role in the reorganization parties. (5) As the probability of asset management companies choosing to acquire bad assets of banks increases, the government’s stabilization strategy has changed from giving specific support to not giving specific support. (6) The government should increase the rewards for hard-working enterprises (such as tax relief and tax-deferred etc.), increase restrictions on enterprises that do not work hard, and provide incentives to asset management companies that cooperate with the debt restructuring process, in order to maximize the interests of all participants.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References


