RESEARCH ARTICLE

Evolutionary Game Simulation Analysis of Government Supervision of Shadow Banking in China

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Abstract

Both the shadow banking and the government regulatory agencies are boundedly rational, and they will constantly adjust their strategies according to the changes in the other party's strategy when making decisions. Therefore, it has become an effective way to explore the government regulatory issues of China's shadow banking with the application of evolutionary game theory. By constructing the evolutionary game model of shadow banking and government regulatory authorities, this paper analyzes the dynamic adjustment relationship between the strategy choice of shadow banking and government regulatory authorities, and concludes that the operating income and cost of shadow banking, the intensity of rewards and punishments and the supervision cost of government regulatory authorities are important factors affecting the decision-making of the two. It is necessary to improve the information disclosure system of shadow banking, strengthen the reward and punishment mechanism for shadow banking, innovate the ways and methods of government supervision of shadow banking, smooth and improve the channels and mechanisms for coordinating government supervision, and guide the compliance operation of shadow banking.

Keywords: shadow banking, government supervision, evolutionary game, simulation.

1 Introduction

Although China's shadow banking has a short history of development, its scale has grown rapidly. It has played an active role in enriching product investment, broadening financing channels, and promoting the development of financial markets. At the same time, its potential risks are also becoming increasingly prominent, the introduction of relevant laws and regulations by government regulatory agencies often lags behind the development of shadow banking, presenting a passive, reactive supervision situation. Problems such as inefficient supervision and lack of guidance for shadow banking have emerged. Therefore, it is necessary to solve the problems of China's shadow banking government supervision as soon as possible, improve the efficiency of government supervision, and promote the healthy development of shadow banking.

The academic research on shadow banking government supervision mainly focuses on the

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following aspects: First, it is clear that the existence of shadow banking is reasonable and requires government supervision. Mitchell [1] proposed that shadow banking functions similarly to banks and should be subject to the same level of supervision as banks; Tarnanidou [2] believes that the current scale of shadow banking is too large, which is likely to bring risks, and its supervision should be strengthened, Elliott et al. [3], Grillet-Aubert et al. [4], Kodres [5] and others pointed out that shadow banking promotes overall social mobility, but due to the long-term regulatory blind zone, if the regulation and restraint are not carried out in time, it is very likely to cause financial risks and bring adverse effects. Therefore, government departments need to strengthen the supervision of shadow banking, restrain and prevent its risks. Second, the supervision of shadow banking should start from the supervision system, information disclosure, risk prevention and other aspects. Yang et al. [6], Xu [7], Thiemann et al. [8], suggest that shadow banking should be included in macro-prudential supervision to curb the pro-cyclicality of shadow banking and reduce systemic risks. Cai et al. [9] concluded that the growth of shadow banking scale will have a negative effect on financial stability based on the principal component analysis method, and suggested penetrating supervision of shadow banking. Zhang et al. [10] believes that shadow banking supervision should be carried out from both internal and external aspects. On the one hand, the shadow banking should strengthen the internal corporate governance and disclosure of information in a timely manner, to set up the complete risk firewall system. On the other hand, shadow banking must continue to improve the construction of the regulatory system, broaden the scope of supervision, and achieve continuous supervision. Li et al. [11] proposed to establish a firewall for cooperation between banking institutions and non-bank financial institutions to prevent shadow banking risks from being transferred to bank balance sheets. Third, we need to prevent radical regulation. Schwarcz [12] proposed that the development of shadow banking should be considered instead of being suppressed blindly. Government supervision must maximize economic utility and minimize potential risks. Pellegrini et al. [13] believe that shadow banking has increased the systemic risk of commercial banks. While strengthening comprehensive control, guiding the standardization of shadow banking operations and resolving systemic risks, government departments should also avoid the occurrence of insufficient and excessive supervision. Fourth, while the government departments take into account China's national conditions and learn from the experience of other countries to supervise shadow banking, they should also pay attention to strengthening the guidance of shadow banking. Hachem [14] proposed that foreign shadow banking government supervision experience should not be copied, but should be adjusted according to China's national conditions. Two types of supervision ideas can be adopted "quasi-banking" and market self-discipline.

In summary, scholars at home and abroad have conducted extensive research on the issue of government supervision of shadow banking, but seldom use the perspective of evolutionary game analysis. In practice, both shadow banking and government regulatory agencies are subject to bounded rationality, and they will constantly adjust to the game in accordance with the changes in the other party's strategies when making decisions. Therefore, this paper applies evolutionary game theory to analyze the evolution and stability of shadow banking, government regulatory agencies and shadow banking government supervision system strategy choices, determines the evolution and stability strategy of the shadow banking government supervision system and the influencing factors of the two strategy choices and analyzes these influences. Starting from these influencing factors, it puts forward suggestions for improving China's shadow banking government supervision.

2 Research design

2.1 Model assumptions

Based on the actual situation of shadow banking and government regulatory agencies, the following assumptions are made:

Hypothesis 1: This evolutionary game model has two game subjects, shadow banking and government regulatory agencies, both of which are bounded rational. In other words, both parties of the game are limited by their own conditions and can only adopt strategies based on known information in the hope of increasing profits as much as possible.

Hypothesis 2: Shadow banking can collaborate with entities such as commercial banks, securities firms, trust companies, insurance companies, and funds to evade supervision through regulatory arbitrage models to maximize profits. However, once such behavior is discovered, it may be punished

Table 1. Parameter settings and meanings of the game model of shadow banking government supervision.

Parameter	Meaning
x	probability of compliant operation of shadow banking
y	probability of loose supervision by government regulators
C_p	the cost of loose supervision by government regulators
C_q	the cost of strict supervision by government regulatory agencies
C_m	the cost of shadow banking when operating in compliance
C_n	the cost of shadow banking operating in violation of regulations
R_m	benefits of shadow banking when operating in compliance
R_n	shadow banking gains when operating in violation of regulations
R_r	benefits of government supervisory authorities when shadow banking is operating in compliance
R_s	loss of government supervisory authorities when shadow banks operate in violation of regulations
F	the government's strict supervision strategy to penalize shadow banking for illegal operations
E	the government's strict supervision strategy rewards shadow banking for compliance operations

by government regulatory agencies such as fines, reorganization, takeover, cancellation, and bankruptcy in accordance with the law. Shadow banking can also choose to operate in good faith and in compliance with relevant laws and regulations of government regulatory agencies.Therefore, the shadow banking's selection strategy is {compliant operation, illegal operation}, and the probability of shadow banking compliant operation is x, and the probability of illegal operation is $1-x(0 \leq x \leq 1)$.

Hypothesis 3: Government regulatory agencies may choose loose supervision and allow the development of shadow banking due to the difficulty of shadow banking supervision, higher costs, and more complicated procedures. It may also be for the healthy and stable development of the financial system and prevent systemic risks, and choose to invest a lot of manpower, material resources and financial resources to strictly supervise shadow banking and impose penalties on shadow banking that operate in violation of regulations. Therefore, the selection strategy of the government regulatory agency is {loose supervision, strict supervision}, and the probability of government regulatory agencies loose supervision is y, and the probability of strict supervision is $1-y(0 \leq y \leq 1)$.

Hypothesis 4: The cost of loose supervision by the government regulatory agency is C_p, and the cost of strict supervision is C_q.Because more human, material, and financial resources are required for strict supervision, so $C_p < C_q$. The government's penalty for illegal operations of shadow banking (such as fines, suspension of business for rectification, takeover, cancellation, declaration of bankruptcy, etc.) during strict supervision is F, and the rewards for compliant shadow banking operations (such as honorary awards, bonuses, tax refunds, financial subsidies, etc.) are E.

Hypothesis 5: The income obtained by shadow banking in compliant operation is R_m and the cost is C_m; the income obtained in illegal operation is R_n, and the cost is C_n, because shadow banking can reduce costs when operating in violation of regulations, such as information disclosure costs and management operating costs, audit costs, taxes, etc., then $C_m > C_n$. When shadow banking is operating in compliance, the benefits (such as bonuses, honor awards, systemic risk reduction, financial system stability, etc.) obtained by the government regulatory agencies are R_r; when shadow banking operate in violation of regulations, the government regulatory agencies suffers losses (such as superior punishment, increased systemic risk, unhealthy development of the financial system and so on) is R_s. Related parameter settings and meanings are shown in Table 1.

2.2 Game payoff matrix

According to the above five assumptions and related parameters, the costs and benefits of shadow banking and government regulatory agencies under different strategic choices can be calculated, and the evolutionary game model of shadow banking government supervision can be constructed, and the game benefit matrix of the two can be obtained, as shown in Table 2.

According to Table 2, the duplicated dynamic equations of shadow banking and government regulatory agencies were solved respectively, and the dynamic evolution process of shadow banking unilateral, government regulatory agencies unilateral and shadow banking government regulatory system was analyzed, and the evolutionary stability strategy of

Table 2. Game income matrix between shadow banking and government regulatory agencies.

Shadow banking	Government regulatory agency	
	loose regulation y	strict supervision $(1-y)$
compliance management x	$R_m - C_m,\ R_r - C_p$	$R_m - C_m + E,\ R_r - C_p - E$
illegal operation $(1-x)$	$R_n - C_n,\ -R_s - C_p$	$R_n - C_n - F,\ F - R_s - C_q$

shadow banking and government regulatory agencies and the constraint conditions for achieving the ideal stable state were obtained.

2.2.1 The evolutionary stability analysis of shadow banking unilateral strategy

The expected benefits of shadow banking's "compliance management" strategy are:

$$U_1 = y(R_m - C_m) + (1-y)(R_m - C_m + E) \quad (1)$$

The expected benefits of shadow banking adopting the strategy of "operating in violation of regulations" are:

$$U_2 = y(R_n - C_n) + (1-y)(R_n - C_n - F) \quad (2)$$

The average expected return of the shadow banking hybrid strategy is:

$$U_A = xU_1 + (1-x)U_2 \quad (3)$$

The dynamic equation of shadow banking replication is:

$$\begin{aligned} F(x) \equiv \frac{dx}{dt} &= x(U_1 - U_A) = x[U_1 - xU_1 - (1-x)U_2] \\ &= x(1-x)(U_1 - U_2) \\ &= (1-x)[R_m + E - C_m - (R_n - C_n - F) - (E+F)y] \end{aligned} \quad (4)$$

According to the basic theory of evolutionary games, when $F(x) = 0$ and $F'(x) < 0$, x^* is an evolutionary stable strategy.

When $F(x) = 0$, $x_1 = 0$, $x_2 = 1$

$$y^* = \frac{R_m + E - C_m - (R_n - C_n - F)}{E + F} \quad (5)$$

Analyze the dynamic evolution process of shadow banking decision according to the solution:

(1) When $y = y^*$, that is $R_m + E - C_m = R_n - C_n - F$, there is always $F(x) = 0$, then x is any value in the interval $[0, 1]$, both are balanced and stable solutions, regardless of the probability of shadow banking's compliance operation, when the total income obtained by shadow banking's compliance operation is equal to the total income obtained by illegal operation, both strategies are stable strategies.

(2) When $y \neq y^*$, that is $x_1 = 0, x_2 = 1$, is the quasi-evolutionary stable point of x, since $0 \leq y \leq 1$, the value of y^* needs to be analyzed.

First, when $y^* < 0$, that is $R_m + E - C_m < R_n - C_n - F$, then $F(0) = F(1) = 0$, $F'(0) < 0$, $F'(1) > 0$, then $x_1 = 0$ is an evolutionary stable state, which means that as long as the total income of shadow banking from compliant operations is less than the total income from illegal operations, no matter what choice the government supervisory department adopts, shadow banking is ultimately stable in illegal operations.

Second, when $y^* > 1$, that is $R_m - C_m > R_n - C_n$, then $F(0) = F(1) = 0$, $F'(0) > 0$, $F'(1) < 0$, then $x_2 = 1$ is an evolutionary stable state, which means that as long as the total income of shadow banking compliant operations is greater than that of illegal operations, no matter what choice the government supervisory department adopts, shadow banking will eventually be stable in compliant operations.

Third, when $0 < y^* < 1$, that is $R_m < R_n + C_m - C_n$ and $R_m + E > R_n + C_m - C_n - F$, there are two cases to discuss the relationship between y and y^*.

When $0 < y < y^* < 1$, then $F(0) = F(1) = 0$, $F'(0) > 0$, $F'(1) < 0$, then $x_2 = 1$ is an evolutionary stable state, it means that when the probability of loose supervision by government regulatory agencies is less than y^*, the shadow bank will eventually be stable in compliant operations.

When $0 < y^* < y < 1$, then $F(0) = F(1) = 0$, $F'(0) < 0$, $F'(1) > 0$, then $x_1 = 0$ is an evolutionary stable state. It means that when the probability of loose supervision by government regulatory agencies is greater than y^*, the shadow bank will eventually stabilize in choosing illegal operations.

To sum up, in the three cases where the probability of

loose supervision by government regulatory agencies is different ($y = y^*$, $y < y^*$, $y^* < y$), shadow banking will obtain three different evolutionary stability strategies. When the probability of loose supervision by government regulatory agencies is equal to $\frac{R_m+E-C_m-(R_n-C_n-F)}{E+F}$, regardless of the value of x, the benefits of compliant operation and illegal operation strategies are the same. Both strategies are evolutionary and stable strategies; when the probability of loose supervision by government departments is less than $\frac{R_m+E-C_m-(R_n-C_n-F)}{E+F}$, $x = 1$ means that the compliant operation is an evolutionary stable strategy of shadow banking; when the probability of loose supervision by government departments is greater than $\frac{R_m+E-C_m-(R_n-C_n-F)}{E+F}$, $x = 0$ means that illegal operations is an evolutionary stable strategy of shadow banking.

2.2.2 An analysis of the evolutionary stability of the unilateral strategy of the government regulatory agencies

In the same way, the expected benefits of the "relaxed supervision" strategy adopted by government regulatory agencies are:

$$U_3 = x(R_r - C_p) + (1 - x)(-R_s - C_p) \quad (6)$$

The expected benefits of the "strict supervision" strategy adopted by the government regulatory agencies are:

$$U_4 = x(R_r - C_q - E) + (1 - x)(F - R_s - C_q) \quad (7)$$

The average expected benefit of the mixed strategy of government regulatory agencies is:

$$U_B = yU_3 + (1 - y)U_4 \quad (8)$$

The replication dynamic equation of the government regulatory agencies are:

$$F(y) = \frac{dy}{dt} = y(U_3 - U_B) = y[U_3 - yU_3 - (1 - y)U_4]$$
$$= y(1-y)(U_3-U_4) = y(1-y)[x(E+F)-C_p-F+C_q] \quad (9)$$

When $F(y) = 0$, $F'(y) < 0$, y^* is an evolutionary stable strategy.

When $F(y) = 0$, $y_1 = 0$, $y_2 = 1$,

$$x^* = \frac{C_p + F - C_q}{E + F} \quad (10)$$

According to the solution, analyze the dynamic evolution process of the government regulatory agencies decision-making:

(1) When $x = x^*$, that is $C_p = C_q - F$, there is always $F(y) = 0$. At this time, any value of y in the interval $[0, 1]$ is a balanced and stable solution, that is, regardless of the probability of loose supervision by government regulatory agencies, the cost of loose supervision by the government department equals the cost of strict supervision minus the penalty for illegal operations of shadow banking under strict supervision, it is a stabilization strategy.

(2) When $x \neq x^*$, that is $y_1 = 0, y_2 = 1$, it is the quasi-evolutionary stable point of y. Since $0 \leq x \leq 1$, the value of x^* needs to be analyzed.

First, when $x^* < 0$, that is $C_p < C_q - F$, then $F(0) = F(1) = 0$, $F'(0) > 0$, $F'(1) < 0$, then $y_2 = 1$ is an evolutionary stable state, indicating that when the cost of strict government supervision is far greater than that of loose supervision, no matter what choice the shadow banking adopts, the government regulatory agencies will eventually stabilize in loose supervision.

Second, when $x^* > 1$, that is, $C_p > C_q + E$, because the previous assumption stipulates that $C_q > C_p$ and $E > 0$, this situation does not exist.

Third, when $0 < x^* < 1$, that is, $C_p > C_q - F$ and $C_p < C_q + E$, there are two cases to discuss the relationship between x and x^*.

When $0 < x < x^* < 1$, then $F(0) = F(1) = 0$, $F'(0) < 0$, $F'(1) > 0$, then $y_1 = 0$ is an evolutionary steady state. It shows that when the probability of shadow banking's compliance operation is less than x^*, the government regulatory agencies will eventually stabilize in strict supervision.

When $0 < x^* < x < 1$, then $F(0) = F(1) = 0$, $F'(0) > 0$, $F'(1) < 0$, then $y_2 = 1$ is an evolutionary steady state. It shows that when the probability of shadow banking compliant operation is greater than x^*, the government regulatory agencies will eventually stabilize in choosing a loose supervision strategy.

To sum up, in the three cases where the probability of shadow banking's compliance operation is different ($x = x^*$, $x < x^*$, $x > x^*$), the government regulatory agencies will get three different evolutionary and stable strategies. When the probability of shadow banking compliant operation is equal to $\frac{C_p+F-C_q}{E+F}$, regardless of the value of y, the benefits of loose supervision and strict supervision strategies are the same, and both strategies are evolutionary and stable strategies; when the probability of shadow banking compliant operation is less than $\frac{C_p+F-C_q}{E+F}$, $y = 0$ means that strict supervision is an evolutionary and stable strategy

of the government regulatory agencies; when the probability of shadow banking compliant operation is greater than $\frac{C_p+F-C_q}{E+F}$, $y = 1$, which means loose supervision is an evolutionary and stable strategy of government regulatory agencies.

2.2.3 *Analysis of the evolution and stability of the hybrid strategy of the shadow banking government supervision system*

As can be seen from the above, the replication dynamic equation of the hybrid strategy of the shadow banking government supervision system is:

$$\begin{cases} F(x) = \dfrac{dx}{dt} = x(1-x)\left[R_m + E - C_m \right. \\ \qquad \left. -(R_n - C_n - F) - (E+F)y\right] \\ F(y) = \dfrac{dy}{dt} = y(1-y)\left[x(E+F)\right. \\ \qquad \left. -C_p - F + C_q\right] \end{cases} \tag{11}$$

Then the partial equilibrium point of the shadow banking government supervision system is (x, y) : $(0,0), (0,1), (1,0), (1,1)$ and (x^*, y^*). Because $0 \le x \le 1, 0 \le y \le 1$, the equilibrium point (x^*, y^*) of the mixed strategy is only valid under the condition of $0 < x^* < 1, 0 < y^* < 1$, where $x^* = \frac{C_p - C_q + F}{E+F}$, $y^* = \frac{R_m + E - C_m - (R_n - C_n - F)}{E+F}$.

Friedman [15] proposed that the stability of the local equilibrium point of the system can be judged by calculating the signs of the Jacobian matrix det$J$ and tr$J$. According to the stability judgment method of the Jacobian matrix J, it can be known that if and only if the local equilibrium point simultaneously satisfies the det$J$ of the matrix greater than 0 and the matrix tr$J$ less than 0, that is,

$$\det J = \alpha_{11}\alpha_{22} - \alpha_{12}\alpha_{21} > 0 \quad \text{and} \quad \mathrm{tr}J = \alpha_{11} + \alpha_{22} < 0.$$

Under these two conditions, the local equilibrium point is stable, that is the evolutionary stability strategy (ESS). If the local equilibrium point satisfies det$J >$ 0 and tr$J > 0$, then this point is an unstable point. If det$J < 0$, this point is a saddle point [16].

From $F(x)$ and $F(y)$, the Jacobian matrix J can be calculated as:

$$J = \begin{bmatrix} \frac{dF(x)}{dx} & \frac{dF(x)}{dy} \\ \frac{dF(y)}{dx} & \frac{dF(y)}{dy} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \tag{12}$$

And,

$$\alpha_{11} = \frac{dF(x)}{dx} = (1-2x)[R_m - C_m + E - R_n + C_n + F - (E+F)y] \tag{13}$$

$$\alpha_{12} = \frac{dF(x)}{dy} = -x(1-x)(E+F) \tag{14}$$

$$\alpha_{21} = \frac{dF(y)}{dx} = y(1-y)(E+F) \tag{15}$$

$$\alpha_{22} = \frac{dF(y)}{dy} = (1-2y)[x(E+F) - C_p - C_q + F] \tag{16}$$

Among them, at the local equilibrium point (x^*, y^*), it can be obtained by calculating formula 13 and formula 16, $\alpha_{11} = 0$, $\alpha_{22} = 0$, tr$J = 0$, which does not satisfy the condition of tr$J = \alpha_{11} + \alpha_{22} < 0$. So the

Table 3. The value of the local equilibrium point of the system.

Equilibrium point	α_{11}	α_{12}	α_{21}	α_{22}
(0,0)	$R_m - C_m + E - R_n + C_n + F$	0	0	$-C_p + C_q - F$
(0,1)	$R_m - C_m - R_n + C_n$	0	0	$-(C_p + C_q - F)$
(1,0)	$-(R_m - C_m + E - R_n + C_n + F)$	0	0	$E - C_p + C_q$
(1,1)	$-(R_m - C_m - R_n + C_n)$	0	0	$-(E - C_p + C_q)$

Table 4. Equilibrium points det$J$ and tr$J$.

Equilibrium point	det$J$	tr$J$
(0,0)	$(R_m - C_m + E - R_n + C_n + F)(-C_p + C_q - F)$	$R_m - C_m + E - R_n + C_n - C_p + C_q$
(0,1)	$-(R_m - C_m - R_n + C_n)(-C_p + C_q - F)$	$R_m - C_m - R_n + C_n + C_p - C_q + F$
(1,0)	$-(R_m - C_m + E - R_n + C_n + F)(E - C_p + C_q)$	$-R_m + C_m + R_n - C_n - F - C_p + C_q$
(1,1)	$(R_m - C_m - R_n + C_n)(E - C_p + C_q)$	$-R_m + C_m + R_n - C_n - E + C_p - C_q$

local equilibrium point (x^*, y^*) cannot be an ESS point. Therefore, we only need to consider the stability of the 4 local equilibrium points $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$. Among them, the values of these 4 local equilibrium points at $\alpha_{11}, \alpha_{12}, \alpha_{21}, \alpha_{22}$ are shown in Table 3, and the values of det$J$ and tr$J$ are shown in Table 4.

Hypothesis 1: when $R_m + E < R_n + C_m - C_n - F$, $C_p > C_q - F$, the local equilibrium point $(0,0)$ is the evolutionary stability strategy (ESS) of the system, that is the shadow bank chooses to operate illegally, and the government regulatory agencies choose strict supervision.

The proof is as follows:

When $R_m + E < R_n + C_m - C_n - F$, $C_p > C_q - F$, the stability analysis results of each local equilibrium point are shown in Table 5.

Table 5. Stability analysis of equilibrium point.

Equilibrium point	det$J$	tr$J$	stability
(0,0)	+	-	ESS
(0,1)	-	-	Saddle point
(1,0)	+	+	Unstable point
(1,1)	-	+	Saddle point

Therefore, when $R_m + E < R_n + C_m - C_n - F$, $C_p > C_q - F$, the evolutionary stability strategy of the system is $(0,0)$, that is, (violating operation, strict supervision).

Hypothesis 2: When $R_m + E < R_n + C_m - C_n - F$, $C_p < C_q - F$, or when $R_m + E \geq R_n + C_m - C_n - F$, $R_m < R_n + C_m - C_n$, $C_p < C_q - F$, at this time, the partial equilibrium point $(0,1)$ is the evolutionary stable strategy of the system, that is, shadow banking choose to operate in violation of regulations, and government regulatory agencies choose loose supervision.

The proof is as follows:

(1) When $R_m + E < R_n + C_m - C_n - F$, $C_p < C_q - F$, the stability analysis results of each local equilibrium point are shown in Table 6.

(2) When $R_m + E > R_n + C_m - C_n - F$, $R_m < R_n + C_m - C_n$, $C_p < C_q - F$, the stability analysis results of each local equilibrium point are shown in Table 7.

Therefore, when $R_m + E < R_n + C_m - C_n - F$, $C_p < C_q - F$, or when $R_m + E > R_n + C_m - C_n - F$, $R_m < R_n + C_m - C_n$, $C_p < C_q - F$, the evolutionary stability strategy of the system is $(0,1)$, that is, (violating regulations, loose supervision).

Table 6. Stability analysis of equilibrium point.

Equilibrium point	det$J$	tr$J$	stability
(0,0)	-	uncertain	Saddle point
(0,1)	+	-	ESS
(1,0)	+	+	Unstable point
(1,1)	-	uncertain	Saddle point

Table 7. Stability analysis of equilibrium point.

Equilibrium point	det$J$	tr$J$	stability
(0,0)	+	+	Unstable point
(0,1)	+	-	ESS
(1,0)	-	+	Saddle point
(1,1)	-	-	Saddle point

Hypothesis 3: When $R_m > R_n + C_m - C_n$, $C_p < C_q - F$, or $R_m > R_n + C_m - C_n$, $C_p > C_q - F$, the local equilibrium point $(1,1)$ is the evolutionary stable strategy of the system. That is, the shadow bank chooses to operate in compliance, and the government regulatory agencies choose to supervise loosely.

The proof is as follows: (1) When $R_m > R_n + C_m - C_n$, $C_p < C_q - F$, the stability analysis results of each local equilibrium point are shown in Table 8.

Table 8. Stability analysis of equilibrium point.

Equilibrium point	det$J$	tr$J$	stability
(0,0)	+	+	Unstable point
(0,1)	-	uncertain	Saddle point
(1,0)	-	uncertain	Saddle point
(1,1)	+	-	ESS

(2) When $R_m > R_n + C_m - C_n$, $C_p > C_q - F$, the stability analysis results of each local equilibrium point are shown in Table 9.

Therefore, when $R_m > R_n + C_m - C_n$, $C_p < C_q - F$, or $R_m > R_n + C_m - C_n$, $C_p > C_q - F$, the evolutionary stability strategy of the system is $(1,1)$, that is (compliant operation, loose supervision).

Hypothesis 4: When $R_m + E > R_n + C_m - C_n - F$, $R_m < R_n + C_m - C_n$, $C_p > C_q - F$, the system does not have an evolutionary stable strategy and there is no stable equilibrium point.

Table 9. Stability analysis of equilibrium point.

Equilibrium point	det$J$	tr$J$	stability
(0,0)	-	+	Saddle point
(0,1)	+	+	Unstable point
(1,0)	-	-	Saddle point
(1,1)	+	-	ESS

The proof is as follows:

When $R_m+E > R_n+C_m-C_n-F$, $R_m < R_n+C_m-C_n$, $C_p > C_q - F$, the stability analysis results of each local equilibrium point are shown in Table 10.

Table 10. Stability analysis of equilibrium point.

Equilibrium point	det$J$	tr$J$	stability
(0,0)	-	uncertain	Saddle point
(0,1)	-	uncertain	Saddle point
(1,0)	-	uncertain	Saddle point
(1,1)	-	uncertain	Saddle point

Therefore, it can be seen from the analysis results that when $R_m+E > R_n+C_m-C_n-F$, $R_m < R_n+C_m-C_n$, $C_p > C_q-F$, the system does not have an evolutionary stable strategy and there is no stable equilibrium point.

Among the four partial equilibrium points $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$, the $(1,1)$ equilibrium point (compliance operation, loose supervision) is the optimal strategy for maximizing the benefits of the shadow banking government supervision system.

3 Simulation analysis

The above is based on the idea of evolutionary game to make a theoretical analysis of the dynamic evolution process of shadow banking and government regulatory agencies strategy selection. In order to more intuitively analyze the evolution process of shadow banking government supervision system under different assumptions, use Matlab R2016a software to carry out simulation experiments to prove the correctness and scientificity of the hypothesis.

In Figures 1 to 6, it is assumed that the initial probabilities of shadow banking and government regulatory agencies are both 0.5, and the abscissa axis represents the evolution time, the ordinate axis represents the probability that shadow banking will choose a "compliant operation" strategy and government regulators will choose a "relaxed supervision" strategy.

(1) Verify hypothesis 1

According to the previous analysis, when $R_m + E < R_n + C_m - C_n - F$, $C_p > C_q - F$, the local equilibrium point $(0,0)$ is the evolutionary stable strategy of the system. Assuming $C_m = 10$, $C_n = 5$, $R_m = 15$, $R_n = 21$, $E = 1$, $F = 3$, $C_p = 4$, $C_q = 6$, the strategic choices of shadow banking and government regulatory agencies are shown in Figure 1.

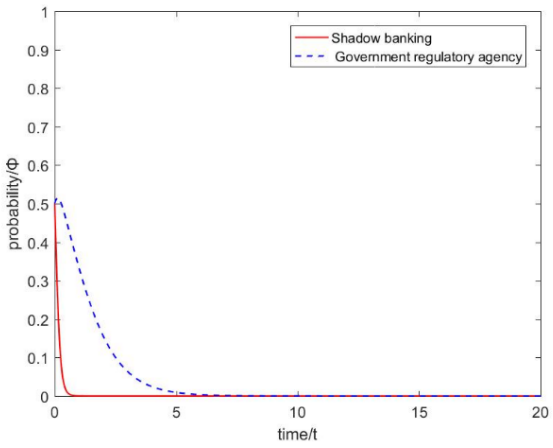

Figure 1. Simulation results of the evolutionary stable point (0,0).

When the parameter setting satisfies the condition of Hypothesis 1, the final evolution of the system is stable when the shadow banking chooses the illegal business strategy, and the government regulatory agencies chooses the strict supervision strategy, that is the local equilibrium point $(0,0)$ is the evolutionary stable strategy of the system.

(2) Verify hypothesis 2

When $R_m + E < R_n + C_m - C_n - F$, $C_p < C_q - F$, the local equilibrium point $(0,1)$ is the evolutionary stable strategy of the system, assuming $C_m = 10$, $C_n = 5$, $R_m = 15$, $R_n = 21$, $E = 1$, $F = 3$, $C_p = 2$, $C_q = 6$, the strategic choices of shadow banking and government regulatory agencies are shown in Figure 2. At the same time, when $R_m + E > R_n + C_m - C_n - F$, $R_m < R_n + C_m - C_n$, $C_p < C_q - F$, the evolutionary stability strategy of the system is also the local equilibrium point $(0,1)$. Assuming $C_m = 10$, $C_n = 5$, $R_m = 15$, $R_n = 21$, $E = 9$, $F = 3$, $C_p = 2$, $C_q = 6$, the strategic choices of shadow banking and government regulatory agencies are shown in Figure 3. When the parameter setting satisfies the two conditions of Hypothesis 2, the final evolution of the system is stable when the

shadow bank chooses the illegal business strategy, and the government regulatory agencies choose the loose supervision strategy, that is, the local equilibrium point $(0, 1)$ is the evolutionary stable strategy of the system.

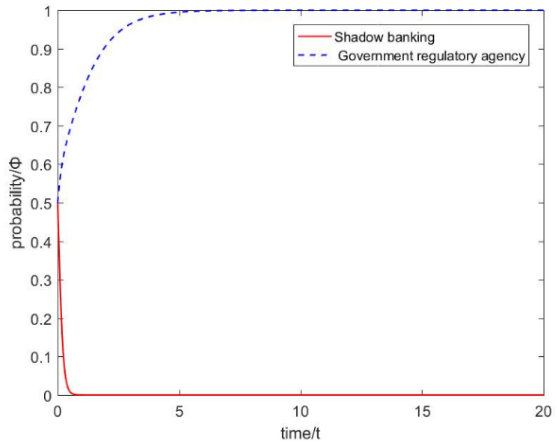

Figure 2. Simulation results of the evolutionary stable point (0,1).

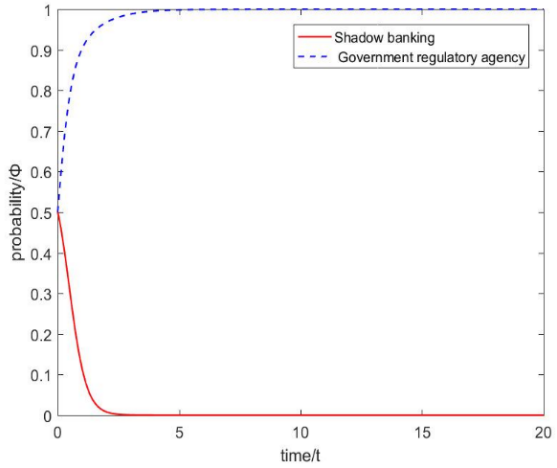

Figure 3. Simulation results of the evolutionary stable point (0,1).

(3) Verify hypothesis 3

When $R_m > R_n + C_m - C_n$, $C_p < C_q - F$, the local equilibrium point $(1, 1)$ is the evolutionary stable strategy of the system. Assuming $C_m = 10$, $C_n = 5$, $R_m = 27$, $R_n = 21$, $E = 1$, $F = 3$, $C_p = 2$, $C_q = 6$, the strategic choices of shadow banking and government regulatory agencies are shown in Figure 4. At the same time, when $R_m > R_n + C_m - C_n$, $C_p > C_q - F$, the evolutionary stability strategy of the system is also the local equilibrium point $(1, 1)$. Assuming $C_m = 10$, $C_n = 5$, $R_m = 27$, $R_n = 21$, $E = 1$, $F = 3$, $C_p = 4$, $C_q = 6$, the strategic choices of shadow banking and government regulatory agencies are shown in Figure 5. When the parameter setting satisfies the two conditions

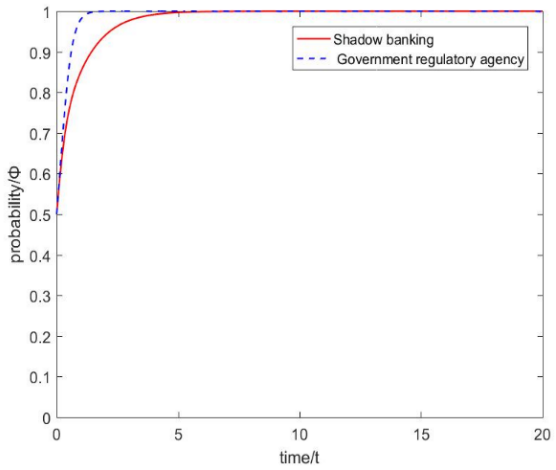

Figure 4. Simulation results of the evolutionary stable point (1,1).

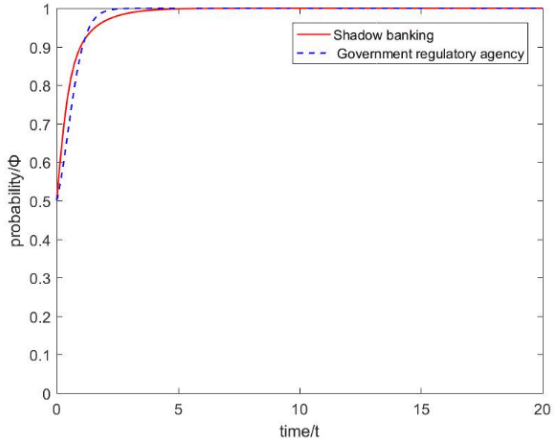

Figure 5. Simulation results of the evolutionary stable point (1,1).

of Hypothesis 3, the final evolution of the system is stable when the shadow bank chooses a compliant business strategy, and the government regulatory agencies choose a loose supervision strategy, that is, the partial equilibrium point $(1, 1)$ is the evolutionary stable strategy of the system.

(4) Verify hypothesis 4

When $R_m+E > R_n+C_m-C_n-F$, $R_m < R_n+C_m-C_n$, $C_p > C_q-F$, the system does not have an evolutionary stable strategy, and there is no stable equilibrium point. Assuming $C_m = 10$, $C_n = 5$, $R_m = 15$, $R_n = 13$, $E = 1$, $F = 3$, $C_p = 4$, $C_q = 6$, the strategic choices of shadow banking and government regulatory agencies are shown in Figure 6. It can be seen that when the parameter settings meet the conditions of Hypothesis 4, the system does not have an evolutionary stable strategy.

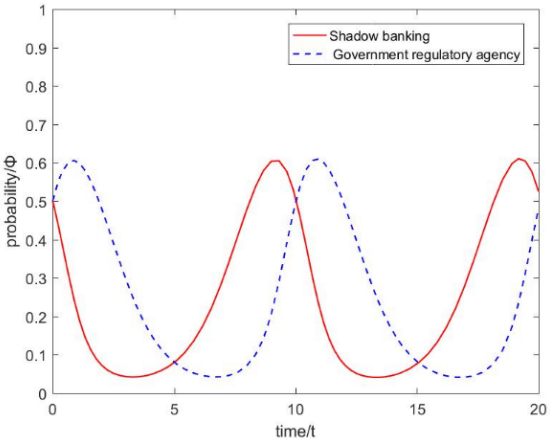

Figure 6. Simulation results without evolutionary stable points.

4 Conclusions and policy recommendations

4.1 Main conclusion

After the above proof of relevant hypotheses and numerical simulation verification, the following conclusions can be drawn:

Conclusion 1: When $R_m > R_n + C_m - C_n$, that is, the benefit of shadow banking under the compliance operation is greater than the benefit under the illegal operation plus the cost saved during the illegal operation (i.e., $C_m - C_n$), regardless of the regulatory strategy adopted by the government regulatory authorities, shadow banking is ultimately stable in choosing a compliant business strategy.

Proof: As can be seen from Hypothesis 3, Table 8 and Table 9, the evolutionary stability strategies of the system are all $(1,1)$. When the shadow bank's compliant operation gains more than the benefit of the illegal operation plus the cost reduction of the illegal operation, that is to say, the benefits of shadow banking under compliant operations are far greater than those under illegal operations ($R_m > R_n + C_m - C_n$, the previous assumption is that $C_m > C_n$, which is equivalent to $R_m > R_n$), regardless of whether the government regulatory agencies chooses strict supervision and satisfies the condition $C_p < C_q - F$, or the government regulatory agencies chooses loose supervision and satisfies the condition $C_p > C_q - F$, the shadow banking will eventually choose a compliant business strategy. After that, shadow banking and government regulatory agencies will continue to play games in the system. Because shadow banking has stabilized in compliance operations, government regulatory agencies have no need for strict supervision, and finally stabilized in loose supervision, and finally the system has stabilized in (compliant operation, loose supervision).

Corollary 1: The probability of shadow banking choosing a compliant business strategy increases with the increase in revenue from compliant operations.

Proof: It can be seen from conclusion 1 that when $R_m > R_n + C_m - C_n$, that is, the benefit of shadow banking under compliance operation is greater than the benefit under illegal operation plus the cost of compliance operation minus the cost of illegal operation, shadow banking is ultimately stable in compliant operations, and this strategy does not change with changes in government regulatory agencies' decisions. Therefore, it is possible to increase the revenue R_m of shadow banking during compliant operations and reduce the revenue R_n of shadow banking during illegal operations, so that the system can evolve faster (compliant operations, loose supervision).

Enlightenment: Government regulatory agencies can improve relevant laws and regulations, maintain fair and orderly competition in the market order, and create a good business environment, reduce the income of shadow banking when operating in violation of regulations, reduce the cost difference between the two strategic choices of shadow banking, and increase the rewards for compliant shadow banking and the punishment for violating shadow banking. In turn, it can increase the value of shadow banking's revenue R_m from compliance operations, and reduce the value of revenue R_n of shadow banking's illegal operations, thereby prompting shadow banking to stabilize their compliant business strategies more quickly.

Conclusion 2: When $R_m + E < R_n + C_m - C_n - F$, that is, the sum of the income from shadow banking compliance operations plus the rewards for shadow banking compliance operations under strict government supervision, is less than the revenue from the illegal operation plus the cost of compliant operation minus the cost of the illegal operation minus the penalty for the illegal operation of shadow banking under the government's strict supervision strategy, regardless of the choice made by government regulators, shadow banking will eventually stabilize itself in illegal operations.

Proof: From Hypothesis 1, Hypothesis 2, Table 5 and Table 6, we can see that the evolutionary stability strategies of the system are $(0,0)$ and $(0,1)$ respectively. At this time, the income of shadow banking from compliant operations plus the reward

for shadow banking compliant operations under strict government supervision is less than the income from illegal operations plus the cost of compliance minus the cost of violation minus the penalty for illegal operations of shadow banks under the government's strict supervision strategy ($R_m + E < R_n + C_m - C_n - F$), the violation of shadow banking under the government's strict supervision strategy. penalties for business operations ($E < F$), that is, the revenue from compliant operations is less than the revenue from illegal operations. That is to say, the income from compliant operations is less than the income from illegal operations. Therefore, no matter whether the government regulatory agencies chooses strict supervision and meets the condition $C_p < C_q - F$, or the government regulatory agencies chooses loose supervision and meets the condition $C_p > C_q - F$, the shadow banking will eventually choose to operate in violation of regulations. However, the government regulatory agencies will choose the strategy that is most beneficial to its own interests according to the cost between the two supervision methods. There is a big difference in the cost of the two supervision strategies, the difference between the cost of strict supervision minus the cost of loose supervision greater than the penalties for illegal operations of shadow banking under the strict supervision strategy of government departments. That is, when the cost of strict supervision is greater than the benefit ($C_p < C_q - F$, equivalent to$C_q - C_p > F$), the government regulatory agencies will eventually stabilize the loose supervision out of cost considerations. And when the cost difference between the two regulatory strategies is not significant, the difference between the cost of strict supervision minus the cost of loose supervision less than the punishment imposed by the government's regulatory authorities for illegal operations of shadow banking under the strict supervision strategy($C_p > C_q - F$, according to the premise, assume that $C_p < C_q$, which is equivalent to $0 < C_q - C_p < F$). For the long-term development of shadow banking, government regulatory agencies will eventually stabilize in choosing a strict regulatory strategy.

Corollary 2: The probability of shadow banking choosing illegal business strategies decreases with the increase of the incentives and punishments of the government regulatory agencies.

Proof: When $R_m + E < R_n + C_m - C_n - F$, that is, the income of shadow banking when they choose to operate in compliance plus the rewards for shadow banking to operate in compliance under strict government supervision less than the revenue from illegal operations plus the cost of compliance minus the cost of non-compliance minus the penalty for illegal operations of shadow banking under the government's strict supervision strategy, shadow banking is stable in illegal operations, and the choice is not affected by government regulatory agencies. Because $R_m + E < R_n + C_m - C_n - F$ is equivalent to $R_m - R_n < (C_m - C_n) - (E + F)$. It can be seen that the income difference and cost difference of shadow banking strategy selection are related to the rewards and punishments of the government regulatory agencies, that is, the value of $E+F$. It shows that the magnitude of the rewards and punishments of the government's regulatory agencies on shadow banking operations has a regulatory effect on the choice of shadow banking strategies.

Enlightenment: By increasing rewards and punishments for shadow banking, the evolution of shadow banking strategies to illegal operations can be delayed.

Conclusion 3: When $C_p < C_q - F$, that is, the cost of loose supervision by government departments is less than the cost of strict supervision minus the penalty for illegal operations of shadow banking under strict supervision. Regardless of whether the shadow bank chooses a compliant business strategy or an illegal business strategy, the government regulatory agency will ultimately choose a loose supervision strategy.

Proof: From Hypothesis 2, Hypothesis 3 and Table 6, Table 7, and Table 8, we can see that the evolutionary stability strategy of the system is (0,1), (0,1) and (1,1). When the cost of the two government strategies differs greatly, and the difference between the cost of strict supervision and the cost of loose supervision is greater than the penalty for illegal operations of shadow banking under strict supervision ($C_p < C_q - F$, equivalent to $C_q - C_p > F$). The choice of government regulatory agencies is not affected by shadow banking, and ultimately stabilizes in choosing loose supervision.

Corollary 3: The probability of government regulatory agencies choosing a loose supervision strategy increases with the increase in the cost of strict supervision, and the probability of choosing a strict supervision strategy decreases with the increase in the cost of strict supervision.

Proof: When $C_p < C_q - F$, equivalent to $C_q - C_p > F$, that is, when the cost under the government's strict supervision strategy is much greater than the

cost under the loose supervision strategy, out of consideration for their own interests, government agencies will increase the probability of choosing a loose supervision strategy.

Enlightenment: Government departments will consider the differences in supervision costs when choosing strategies. They can start by reducing the cost of government supervision and improving supervision efficiency, and strengthen the supervision of shadow banking by government departments.

4.2 Policy recommendations

Through the analysis of the evolutionary game model of shadow banking government supervision, combined with the conclusions and inspirations, the shadow banking government supervision can be divided into three stages to elaborate:

The first stage: In the initial stage of the supervision of shadow banking by the government regulatory agencies, there are fewer laws, regulations and systems. Because of the lack of legal support, various departments cannot timely supervise and implement penalties for illegal operations of shadow banking. At this time, the cost of illegal operation of shadow banking is lower, and the benefits obtained are higher, that is, when $R_m + E < R_n + C_m - C_n - F$, in order to maximize its own interests, shadow banking will eventually stabilize themselves in illegal operations.

The second stage: With the development of shadow banking, government departments have improved the laws and regulations of shadow banking supervision, and began to investigate and deal with shadow banking violations, and impose penalties such as fines, reorganization, takeover, cancellation, etc., to increase the cost of shadow banking's illegal operations, thereby reducing the benefits of illegal operations. However, the transformation of shadow banking behavior and the improvement of the government supervision system need to go through a complex and long stage, and shadow banking products are constantly innovating, and the government regulatory agencies policies are lagging behind. Therefore, during this period, the compliant operation strategy and the illegal operation strategy of the shadow bank, the loose supervision strategy and the strict supervision strategy of the government regulatory agencies coexist.

The third stage: Under the constraints of various regulatory systems and the reward-and-punishment mechanisms of government regulatory agencies, the cost of illegal operations in shadow banking continues to rise, while the benefits obtained gradually decline. To maximize returns, shadow banking gradually evolves into compliant operations. Once shadow banking stabilizes under a compliance-oriented strategy, if government regulatory agencies continue to adopt a strict supervision approach, the additional regulatory costs will outweigh the corresponding benefits. In this context, in order to maximize their own interests, regulatory agencies gradually lose the incentive to maintain strict supervision. As a result, supervision evolves from initially being strict to becoming relatively loose, ultimately reaching an optimal stable state characterized by compliant operations and loose supervision, which maximizes overall system efficiency. However, in practice, while shadow banking may adopt compliant business strategies, it is overly idealistic to assume that regulatory agencies will consistently choose loose supervision. The transformation of shadow banking behavior and the improvement of government regulatory systems involve a complex and lengthy process.

At present, the government supervision of shadow banking in China is in the second stage. The compliant operation strategy and illegal operation strategy of shadow banking, the loose supervision strategy and strict supervision strategy of government regulatory agencies coexist. From the previous analysis, it can be seen that the operating income, operating costs of shadow banking, the incentives and penalties of government regulatory agencies for shadow banking, and government regulatory costs are important factors that affect the strategic choices of shadow banking and government agencies. Therefore, to promote the compliance operation of China's shadow banking, solve the problems of China's shadow banking government supervision, and improve the supervision efficiency of government departments, we can start from these influencing factors.

4.2.1 *Improve the shadow banking information disclosure system*

One of the characteristics of shadow banking is information asymmetry, less information disclosure, or even false information, and low transparency. As a result, financial consumers cannot understand product risks, and government regulators cannot grasp the actual development and operational risks of shadow banking. Therefore, it is necessary to improve the information disclosure system of shadow banking. First, establish an information sharing platform and strengthen information disclosure. Unify financial

statistics and monitoring standards, clarify the standards and norms for shadow banking information disclosure, Including the name of shadow banking institution, product name, leverage ratio, issuance scale, product sales, capital flow, investment operation, valuation and settlement, etc., and incorporate all aspects of business operations into the information management system. For the innovative products of shadow banking, the comprehensiveness and authenticity of data information must be strictly required, the scale of development and risk level of shadow banking must be strictly controlled, and relevant data shall be disclosed to the market in a timely manner. Second, establish an information disclosure reward and punishment mechanism, launch an online information disclosure system, and clearly stipulate the regulatory powers and obligations of the shadow banking information disclosure regulatory authorities. Give rewards to shadow banking institutions that actively regulate information disclosure, and increase penalties for institutions that violate information disclosure regulations to increase the cost of violations. Third, strengthen the management of third-party credit rating agencies, emphasize the responsibilities and obligations of credit rating agencies for information disclosure, and require them to ensure an objective, fair and true evaluation of the rating targets, and supervise the rating process to ensure the sunshine of rating transparent.

4.2.2 Strengthen the reward and punishment mechanism for shadow banking

For shadow banking, operating costs and operating income are important factors that affect their decision-making. Government regulatory agencies should also proceed from these two factors, increase the reward and punishment mechanism for shadow banking, reward shadow banking for compliant operations, penalize illegal operations, and guide shadow banking to operate in compliance.

When the operating cost is not much different, the root cause of shadow banking's illegal operation is that the income from illegal operation is far greater than the income from compliant operation. Government regulatory agencies can severely crack down on illegal operations of shadow banking by increasing the income of shadow banking during compliant operations and increasing penalties for illegal operations. First, increase the penalties for illegal operations and reduce the income of shadow banking' illegal operations, such as increasing fines, ordering business suspension for rectification, and revoking business licenses. Second, increase the income of shadow banking compliance operations, increase the incentives for compliance operations, such as granting innovation rewards, business subsidies, fee subsidies, honor awards, bonuses, tax incentives, etc., to enhance the enthusiasm of shadow banking compliance operations. Third, give spiritual and material rewards to outstanding practitioners, and implement strict penalties and industry bans on relevant business practitioners who violate regulations. It is required to conduct qualification assessment and continuous training for shadow banking practitioners, strengthen ideological education for shadow banking practitioners, and enhance their professionalism and self-discipline.

4.2.3 Innovative methods and approaches for government supervision of shadow banking

Government regulatory agencies should actively learn, master and use new technologies to implement supervision, and increase investment in supervision technology. Introduce big data, cloud computing, blockchain, artificial intelligence, etc. into the supervision of shadow banking, and set up new supervisory functions. Collect shadow banking transaction data, analyze the flow of funds, build a risk prediction model, predict the probability of transaction violations and provide early warnings. To help government regulatory agencies to more quickly identify potential risks and detect shadow banking irregularities, and formulate effective and effective regulatory measures in a timely manner. To prevent shadow banking from happening before it happens, and realize effective supervision, it is necessary to use the power of financial technology to conduct intelligent supervision of shadow banking. Enhance the government's ability to collect information on shadow banking operations, improve regulatory efficiency, promote scientific regulatory decision-making, accurately crack down on illegal operations of shadow banking, improve the level of supervision, and realize the upgrade of shadow banking supervision.

4.2.4 Smooth and improve government supervision information channels and coordination mechanisms

The trend of cross-institutional and cross-departmental mixed operation is obvious of shadow banking in China, and government departments are facing the phenomenon of increasing supervision difficulty, delayed supervisory communication, excessive supervision cost, and shirking responsibility. In

order to eliminate this phenomenon, the regulatory coordination mechanism between government departments should be improved. First of all, an information sharing network system must be established between regulatory agencies. Since China's shadow banking is mainly a mixed business model, various regulatory agencies should divide the shadow banking supervision work and establish a unified reporting system. The supervision work information is uploaded and filed online in a timely manner to open up information sharing channels between supervision departments, facilitate communication with each other, and reduce the cost of repeated supervision. Second, the central regulatory authority and the local financial government regulatory authorities should be integrated and interconnected. The local financial government regulatory agencies must implement the policies formulated by the central supervision department. The local financial government regulatory agencies can also give feedback to the central supervision department when it has new supervision. Strengthen the communication and coordination between the central and local regulatory agencies, and enhance the enforcement of supervision. Finally, government departments must effectively combine micro-prudential supervision and macro-prudential supervision, and clarify the scope of responsibility of each regulatory department. Coordinate the organizational structure, leadership authority, supervision scope, and degree of assistance in the supervision mechanism to avoid fragmentation of supervision boundaries and realize the efficiency and comprehensiveness of supervision.

5 Deficiencies in the study

A comprehensive review of this paper reveals several limitations that hopefully can be addressed in future studies. Firstly, shadow banking is a recent emergence in the financial industry, and the statistical criteria for its data are still ambiguous, with insufficient public data available. Consequently, this paper mainly focuses on the qualitative analysis of government regulation of shadow banks, with less emphasis on quantitative analysis. Secondly, the evolutionary game model for government regulation of shadow banks involves abstraction and simplification, limiting the analysis to only two players: shadow banks and government regulatory authorities. The assumptions and parameters set are limited, and in reality, financial consumers, as stakeholders, also influence the decision-making of the players. Additionally, factors such as news media, informed whistleblowers, third-party institutions, and international regulatory organizations can also affect the model's operation, making its actual mechanism potentially more complex. Thirdly, shadow banks operate in a mixed-business environment involving multiple financial sectors like commercial banks, trusts, securities, insurance, and funds, exhibiting diverse forms. Studying them requires a multifaceted theoretical foundation. Given the author's limited academic capabilities, some understandings of related fields may be inappropriate, and the suggestions proposed may still need further development.

6 Future Prospects

Currently, there is limited public disclosure of data related to shadow banks. The author hopes that in the future, more data will be available to support a deeper exploration and analysis of the operational models of shadow banks and government regulation. Additionally, while this paper has abstracted and simplified the evolutionary game model for government regulation of shadow banks, future studies could consider establishing a tripartite evolutionary game model involving government regulatory authorities, shadow banks, and consumers. Incorporating factors like news media, informed whistleblowers, third-party institutions, and international regulatory organizations can broaden the scope of research on government regulation of shadow banks and enhance the understanding of the influencing factors, making the model more aligned with actual conditions.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

References

[1] Mitchell, A. (1999). Out of the shadows. *Journal of Marketing Management*, *15*(1-3), 25-42. [CrossRef]

[2] Tarnanidou, C. I. (2016). EU financial collateral arrangements and re-hypothecation in the shadow of 'shadow banking': To further regulate or not?. *Journal of banking regulation, 17*(3), 200-238. [CrossRef]

[3] Elliott, D., Kroeber, A., & Qiao, Y. (2015). Shadow banking in China: A primer. *Economic Studies at Brookings, 3*(2015), 1-7.

[4] Grillet-Aubert, L., Haquin, J. B., Jackson, C., Killeen, N., & Weistroffer, C. (2016). *Assessing shadow banking–non-bank financial intermediation in Europe*. ESRB: Occasional Paper Series, (2016/10). [CrossRef]

[5] Kodres, L. E. (2013). What is shadow banking. *Finance and Development, 50*(2), 42-43.

[6] Yang, L., van Wijnbergen, S., Qi, X., & Yi, Y. (2019). Chinese shadow banking, financial regulation and effectiveness of monetary policy. *Pacific-Basin Finance Journal, 57*, 101169. [CrossRef]

[7] Xu, M. (2023). The Coordination Between Macro-Prudential Supervision and Monetary Policy—From the Perspective of Financial Stability. *Frontiers in Management Science, 2*(4), 60-79.

[8] Thiemann, M., Birk, M., & Friedrich, J. (2018). Much ado about nothing? Macro-prudential ideas and the post-crisis regulation of shadow banking. *KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie, 70*(Suppl 1), 259-286. [CrossRef]

[9] Cai, J., & Wang, A. (2022, December). Shadow Bank Scale and Financial Risk Prevention and Control Ability An Empirical Study Based on Principal Component Analysis. In *2022 International Conference on mathematical statistics and economic analysis (MSEA 2022)* (pp. 107-114). Atlantis Press. [CrossRef]

[10] Zhang, J., & Xu, L. (2023). Local supervision of Chinese shadow banking. *Journal of Banking Regulation, 24*(3), 337-356. [CrossRef]

[11] Li, J., Hsu, S., & Qin, Y. (2014). Shadow banking in China: institutional risks. *China Economic Review, 31*, 119-129. [CrossRef]

[12] Schwarcz, S. L. (2011). Regulating Shadow Banking: Inaugural Address for the Inaugural Symposium of the Review of Banking & Financial Law. *Rev. Banking & Fin. L., 31*, 619.

[13] Pellegrini, C. B., Cincinelli, P., Meoli, M., & Urga, G. (2022). The role of shadow banking in systemic risk in the European financial system. *Journal of Banking & Finance, 138*, 106422. [CrossRef]

[14] Hachem, K. (2018). Shadow banking in China. *Annual review of financial economics, 10*(1), 287-308. [CrossRef]

[15] Friedman, D. (1991). Evolutionary games in economics. *Econometrica: journal of the econometric society*, 637-666. [CrossRef]

[16] Wan, X., Xiao, S., Li, Q., & Du, Y. (2021). Evolutionary policy of trading of blue carbon produced by marine ranching with media participation and government supervision. *Marine Policy, 124*, 104302. [CrossRef]



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