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Asymmetric Evolutionary Game between Financial Innovation and Financial Regulation ---- Punishment or Encouragement

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Abstract: After the financial crisis in 2007, the high risk brought by financial innovation has aroused widespread concern and thinking again. The measures to curb financial innovation in various countries have become increasingly severe. However, under the background of the supply-side reform proposed by the Chinese government, the reform of the financial capital elements of the supply root is imperative. Therefore, how to curb the risk of innovation in financial institutions effectively, while encouraging innovation in favor of financial supply side of the reform of compliance, become an important issue to be solved. Based on the limited rationality, the long - term dynamic game equilibrium between financial institutions and regulators and its impact on financial system and financial market is analyzed by constructing asymmetric evolutionary dynamic game model. Then, analyzing the relevant factors of long-term equilibrium, and puts forward the regulatory measures which are conducive to encouraging the reform of compliance and the reform of financial supply-side.

Keywords: Financial Innovation, Financial Regulation, Evolutionary Game

1. Introduction

After the outbreak of the US financial crisis in 2007, the high risk of financial innovation concern aroused once again. Financial innovation to the US real estate industry and the financial industry had brought a very objective profit, at the same time, speculators on the risk of chasing had become unprecedented madness. The complex financial innovation which is too much optimistic and not to be controlled is the initiator of this crisis, all kinds of credit rating agencies blindly participate in the outbreak of the crisis. But in the final analysis, or the supervision of financial regulators are not in place, the lack of appropriate regulatory technology and early warning system is imperfect, so that all kinds of complex and highly innovative derivatives have the opportunity to be in the financial system [1]. Wantonly rampant and continue to enlarge the risk. In the end, the subprime mortgage crisis, which originated from real estate mortgages, quickly turned into a financial crisis that spurred the financial system and brought a blow to the real economy, making the United States and the global economy a recession and unemployment. The duration of the crisis is long and the scope of influence is unprecedented. Gualandri & Landi [2] argues that the main reason for the financial crisis is that the pace of financial regulation is lagging behind the integration of financial services. China is now in the critical period of reform and transformation, supply-side reform is also mentioned at an unprecedented height, the supply of the source of financial capital reform is also imperative. Therefore, in the context of new international and domestic economic development, how regulators should adopt appropriate regulatory strategies to encourage financial institutions to comply with financial innovation, promote healthy and sustainable development of the entire financial industry, and inhibit illegal innovation to maintain the orderliness and stability of the entire financial market has become one of the most urgent issues.

The existing research through the dynamic analysis of financial innovation and financial regulation found that innovation costs, innovation excess returns, regulatory costs and the punishment of the regulatory authority and other factors will affect the long-term balance of the two sides of the game, and increase the punishment of can effectively regulate

the conclusions of financial innovation(Tong Wu et al [3], Xiaolei Cui et al [4], Cheng Li et al [5] [6], Chun He [7], Jingxian Wang and Min Yang [8], Zongtai Li and Zhongwei He [9], Wenwen Yan [10], Yanhua Li [11], Yanghui Ou [12]). However, aggravating the penalties for illegal innovation is bound to combat the innovation of financial institutions. The fundamental purpose of regulatory regulation is not to curb innovation, but to promote financial institutions to take the initiative to reduce the adverse development of financial markets, while increasing reasonable compliance innovation which is conducive to stabilizing financial system and in line with the financial supply side of the reform requirements. Based on this, this paper attempts to analyze how to add a reward to the compliance innovation of financial institutions and then achieve motivating the subjective initiative of Financial Institutional compliance innovation from the internal mechanism.

2. The Construction of Asymmetric Evolutionary Dynamic Game Model

2.1. Assumptions

Assumption 1: Both sides of the game are financial institutions and regulators, and they are bounded rational economic people [13].

Assumption 2: The innovation of financial institutions is divided into compliance innovation and illegal innovation.

Assumption 3: Regulatory strategy options for active regulation and negative regulation. Regulators give the appropriate incentives for the compliance innovation and punish a certain degree of punishment, respectively.

2.2. Evolutionary Game Model

Evolutionary game model usually uses the following formula to simulate the dynamic equations of the dynamic adjustment process,

$$\frac{dx}{dt} = x \bullet (U_k - U) \tag{1}$$

Where X is the ratio of strategy K in a population, Uk is the expected return for strategy k, and U is the average return for all strategies. dx/dt is the change rate in the number of groups of strategy k over time. The basic idea of reproducing a dynamic equation is that if the result of strategy K is superior to the average, the proportion of the selected group of the strategy will increase throughout the population.

The following assumptions are made on variables that are related to the choice of strategy, cost and benefit of financial institutions and regulators:

Table 1. *The Construction Meaning of Variables in Dynamic Model of Evolutionary Game between Financial Institutions and Regulators.*

Game Participants	Variable	Meaning
FI	P	Percentage of financial institutions with illegal innovation strategies;
	1-P	Percentage of financial institutions with compliance innovation strategies;
	C_1	When the regulator is actively supervising, the cost of the innovation by the financial institution (in order to simplify the analysis, consider only the costs incurred by the regulator);
	d	the normal return of financial institutions to obtain compliance;
	d*	excess proceeds from financial institutions with illegal innovation strategies;
	V	financial institutions which carry out compliance innovation was detected by the regulatory authorities to receive the reward;
	F	Financial institutions which carry out illegal innovation was found by the regulatory authorities to accept a fine.
RA	q	The proportion of regulators that adopt an active regulatory strategy;
	1-q	The proportion of regulators that adopt a negative regulatory strategy;
	C_2	Regulatory costs incurred by regulators in actively monitoring the innovation of financial institutions (assuming that the cost of the regulator's negative supervision is zero);
	U_1	Revenue from regulatory agencies when financial institutions adopting a compliance innovation strategy;
	U_2	Revenue from regulatory agencies when financial institutions adopting an illegal innovation strategies;
	U_3	Financial institutions to use illegal innovation, the loss of the regulatory authorities to take negative supervision. (Including the economic losses caused by the loss of the reputation of the regulatory agencies, and $U_3 > C_2$);

Note: RA and FI represent Regulatory Agencies and Financial Institutions, respectively.

2.3. Game Strategy and Income Matrix

As mentioned above, we can draw the profit and loss situation of financial institutions and financial regulators under various strategies, as shown in Table 2:

Table 2. *Asymmetric evolutionary game matrix between financial institutions and regulatory agencies.*

FI \ RA	Active supervision (q)	Negative supervision (1-q)
Compliance innovation（1-P）	$d+V-C_1, U_1-C_2$	d, U_1
Illegal innovation（P）	$d+d*-C_1-F, U_1-C_2$	$d+d*, U_2-U_3$

2.4. Game Equilibrium Analysis

Table 3. *The expected return of RA and FI's strategic choices.*

RA	The expected return of taking active regulatory strategy:	$U_q = (1-p)\bullet(U_1 - U_2) + p\bullet(U_2 - C_2)$
	The expected return of taking negative regulatory strategy	$U_1 - q = (1-p)\bullet U_1 + p\bullet(U_2 - U_3)$
	Total expected return:	$U_1 = q * U_q + (1-q) * U_1 - q$
	Replication dynamic equation:	$F(q,p) = \frac{dq}{dt} = q\bullet(U_q - U_1) = q\bullet(1-q)\bullet(p\bullet U_3 - C_2)$
FI	The expected return of choosing illegal innovation	$U_p = q\bullet(d + d^* - C_1 - F) + (1-q)\bullet(d + d^*)$
	The expected return of taking compliance innovation	$U_1 - p = q\bullet(d + V + C_1) + (1-q)\bullet d$
	Total expected return:	$U_2 = p\bullet U_p + (1-p)\bullet U_1 - p$
	Replication dynamic equation:	$G(q,p) = \frac{dp}{dt} = p\bullet(U_p - U_2) = p\bullet(1-p)\bullet\left[d^* - q\bullet(F+V)\right]$

In Evolutionary Game Model, the strategy combination of the two sides to achieve evolutionary stability is called evolutionary stabilization strategy (ESS), also known as local equilibrium point. The local equilibrium point is the solution that makes the two Replication dynamic equation contain zero at the same time, that is:

$$F(q,p) = \frac{dq}{dt} = 0 \tag{3}$$

$$G(q,p) = \frac{dp}{dt} = 0 \tag{4}$$

we can find the local equilibrium point of the replication dynamic system, include: $(q,p): E_1(0,0)$; $E_2(0,1)$; $E_3(1,0)$; $E_4(1,1)$ and $E_5(d^*/F+V, C_2/U_3)$ .but, E_5 is slightly different from other equilibrium points. Due to $C_2 < U_3$, Only when $d* < F+V$ （that is if $q<1$ and $p<1$ ）, E_5 is a local equilibrium point.

To further determine whether the local equilibrium point is evolutionally stable equilibrium point. We need discuss the $F(q,p)$ and $G_p(q,p)$ in the local equilibrium point of the value of the symbol.

Table 4. *Stability of local equilibrium points.*

Ep(q,p) \ Cf	$d^* > F+V$		$0 < d^* < F+V$	
$E_1(0,0)$	$G_p(q,p) = d^* > 0 \quad F_q(q,p) = -C_2 < 0$	Saddle point	$F_q(q,p) = -C_2 < 0 \quad G_p(q,p) = d^* > 0$	Saddle point
$E_2(0,0)$	$F_q(q,p) = U_3 - C_2 > 0$ $G_p(q,p) = -d^* < 0$	Saddle point	$F_q(q,p) = U_3 - C_2 > 0 \quad G_p(q,p) = -d^* < 0$	Saddle point
$E_3(0,0)$	$F_q(q,p) = C_2 > 0$ $G_p(q,p) = d^* - (F+V) > 0$	Unstable-point	$F_q(q,p) = C_2 > 0$ $G_p(q,p) = d^* - (F+V) < 0$	Saddle point
$E_4(1,1)$	$F_q(q,p) = C_2 - U_3 < 0$ $G_p(q,p) = (F+V) - d^* < 0$	Stability point	$F_q(q,p) = C_2 - U_3 < 0$ $G_p(q,p) = (F+V) - d^* > 0$	Saddle point
$E_5(d^*/F+V, C_2/U_3)$	$d^*/(F+V) > 1$	NEP	$F_q(q,p) = 0 \quad F_q(q,p) = 0$	Stability point

Note: Ep and Cf represent Equilibrium point and Classification, respectively. NEP means Non local equilibrium point.

Two specific cases listed in Table 4 are analyzed in detail.

Case 1: If $d^* > F+V$, immediately, $d^*/(F+V) > 1$, $E_4(1,1)$ is the stability point.

Both bounded rational sides after a long period of repeated game, financial institutions eventually tend to choose "illegal innovation" strategy, and financial regulators will all choose "active supervision" strategy. This situation generally occurs in the financial market that the operation mechanism is not perfect, and there is a very fierce competition between financial institutions. In order to achieve more additional benefits, financial institutions have been risky to innovate. In the face of the illegal innovation of financial institutions, regulators play a full regulatory role, and actively carry out financial supervision to increase penalties for illegal innovation to stabilize the order and security of financial markets. In the face of more severe penalties, the pursuit of maximization of interests of financial institutions can only be further through the illegal innovation to avoid the regulatory constraints brought about by the economic losses. This makes the game between financial institutions and financial regulators enter a long-term vicious circle. The self-restraint of financial institutions is getting worse, which makes the financial risk coefficient implied in the whole financial market and the possibility of the financial crisis increase. Therefore, the stable point at this time will be an inefficient equalization

point. However, if there is government support at this time, the financial regulators within the controllable range will violate the innovation punishments into the rewards of compliance innovation, which in essence changes the relative benefits of compliance innovation and illegal innovation in financial institutions, then the two sides of the game state will be improved to achieve a more efficient balance.

Case 2: If $0 < d^* < F + V$, $E_5(d^* / F + V, C_2 / U_3)$ is the evolutionary stability point.

q=d*/F +V, p=C2/U3 represent the transformation point that financial regulators and financial institutions adopt a different strategic proportion, respectively.

Both bounded rational sides after a long period of repeated game, the ratio of financial institutions that choose the strategy of "illegal innovation" is C2/U3; the proportion of financial regulators who choose "active regulatory " strategy is d*/F +V. At the same time, the entire financial market will be in a relatively healthy and orderly state. Due to the fact that the financial institutions have the incentive to innovate violently, but because of the proper supervision of the financial regulators and the effective constraints of the financial market mechanism, financial innovation and financial supervision will eventually reach a relatively stable equilibrium state.

2.5. Analysis of Influencing Factors of Dynamic Game

By analyzing the evolutionary stability point E_5 (d*/F +V, C_2/U_3) in the above scenario, we can see that when the stable equilibrium state of the financial market is reached, the proportion of the financial institutions who choose the "illegal innovation" and the proportion of financial regulators who choose "active regulatory " will be affected by the size of the five variables of d*, F, V, C_2, U_3. Among them, the three variables F, V and C2 can be controlled by financial regulators. By changing the size of F, V, and C_2, regulators can influence the results of game equilibrium.

(1) Assuming that the other variables remain the same, financial regulators increase the value of C_2 by increasing the regulatory cost of the "active regulatory" strategy. To reduce regulatory costs, regulators tend to loosen financial regulation, and the proportion of regulators that choose "negative regulatory" strategies is increasing. This will lead to financial institutions do not have to take into account the regulatory authorities, not only its innovation costs C_1 may be significantly reduced, illegal innovation will also be enhanced, the proportion of selecting the "illegal innovation" strategy of financial institutions will also be significantly increased.

(2) Assuming that other variables remain unchanged, financial regulators increase the penalties for illegal innovation of financial institutions. At this point, the excess returns that financial institutions choose to violate the innovation may be offset in whole or in part by the penalty, and the total gain d+d*-C_1-F is significantly lower than before. And the choice of compliance innovation needs to be paid more costs, so the driving force for compliance innovation is not very strong. When F is very large, even more than the excess proceeds of illegal innovation, in order to avoid the huge losses caused by illegal innovation, financial institutions would tend to give up the "illegal innovation" strategy.

Because of the increases for F, d*/(F +V) will be reduced, that is, the proportion of selecting the "active regulatory" of regulators will decline. Financial institutions will once again tend to use regulatory loopholes to choose "illegal innovation" to obtain excess returns d* to make up for fines and losses before. Therefore, regulators will further increase penalties, so that financial institutions can not really serve to curb illegal innovation and encourage compliance innovation.

(3) Assuming that other variables remain the same, financial regulators increase incentives for compliance innovation in financial institutions. The total return d+d*-C_1-F of the financial institution's risk-taking innovation is unchanged, but the total income d+V-C_1 obtained by the compliance innovation increases with the increase of V. At this point, financial institutions will trade-off between "illegal innovation" and "compliance innovation". When V is gradually increased to a certain level, the benefits of compliance innovation are even more substantial compared to the lower excess returns associated with the risk of "illegal innovation" and which help financial institutions establish their own positive image and maintain good reputation. Therefore, financial institutions will be more inclined to choose "compliance innovation" strategy. Even if the number of regulators who choose "active regulatory" at this time declines, the motivations for financial institutions to change their strategies will not be strong because the benefits of V are large enough.

From the above analysis of F, V, we can see that the "punitive measures" and "incentive measures" can reduce the innovation of the violation to a certain extent, but the "incentive measures" are more conducive to encourage the financial institutions to choose "compliance innovation", thus promote the healthy, sustained and stable development of financial markets.

3. Conclusions and Policy Recommendations

This paper constructs the asymmetric evolutionary dynamic game model between financial institutions and financial regulators from the perspective of bounded rationality. Using this model, it was found that financial institutions and financial regulators have experienced "illegal innovation - active regulatory - compliance innovation - negative regulatory ", after the cycle of the game, both sides will achieve an evolutionary equilibrium state [14]. It was also found that the excess returns and penalties for the illegal innovation, the rewards of compliance innovation, the cost of active regulation, and the loss of benefits in negative regulation all have impact on the strategic choice of financial institutions and regulators and the ultimate balance. Among them, the financial regulators can change the cost of supervision, the penalties for the illegal innovation, and the rewards of compliance innovation to affect the outcome of the

two sides of the game, and then to guide financial institutions to take compliance innovation which is conducive to the stability of the financial markets. Therefore, in order to meet the needs of China's financial supply-side reform more quickly and promote the stability and development of China's financial market. China's financial regulatory agencies should take into account the common impact of these three factors in the regulatory process, and highlight the "incentive measures" (including bonuses, material and other explicit rewards, also including good reputation, transmission of potential signals and other hidden incentives) which plays a role in guiding and incenting compliance innovation.

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