



Evolutionary Game Analysis of Financial Innovation and Regulation

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Authors' contributions

This work was carried out in collaboration between both authors. Author M-CL designed the study, performed the Evolutionary Game Analysis and wrote the first draft of the manuscript. Author L-ES managed the analyses of this study. Both authors read and approved the final manuscript.

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ABSTRACT

Financial innovation and financial supervision promote each other mutually. Financial regulation is the motive of financial innovation furthers the improvement of financial regulatory system. Since financial crisis due to excessive financial innovation and the lack of financial regulation still happens. This paper build the dynamic game model and then build the asymmetric evolutionary game model between financial innovation institutions and the regulation authority and analysis their long term dynamic game relationship. Under the objectives, it studies the influence factors of financial innovation and regulation and the interaction between these factors. Through the equilibrium analysis of the game, the paper draws the conclusion that regulators can design the embedded regulatory system. Through the asymmetric evolutionary game analysis, the paper derived the long-term evolutionary stable equilibrium of the innovation and supervision. Finally, the paper gives some suggestions on how to strength the regulation for financial innovation.

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1. INTRODUCTION

A lot has been achieved since the financial crisis in the area of banking regulation and supervision. Many developed countries currently face complex problems and high uncertainty as a result of an important economic crisis [1]. The current crisis has negatively affected both private businesses and public-sector services [2]. Innovations can affect financial intermediation and the effective working of the financial intermediation process is inherently a matter of public interest [3]. Innovation should be seen as a natural aspect of the workings of a competitive system. Thus, the ideal policy approach is to find an appropriate balance between preserving safety and soundness of the system and allowing financial institutions and markets to perform their intended functions. Regulators and supervisors will need enhanced capabilities to effectively handle the complexities of today's financial markets. Financial innovation is the act of creating and then popularizing new financial instruments, as well as new financial technologies, institutions and markets [4]. However financial crisis due to excessive financial innovation and the lack of financial regulation still happens. Evolutionary game dynamics is the application of population dynamical methods to game theory. Under the unbalanced background of the financial system, enterprises, banks and regulatory agencies is a complex relationship of the game. Therefore, this paper use evolutionary game method analysis of financial institutions should be solving the problem of how to control the intensity of regulatory, and then discuss the further development of financial notes.

2. LITERATURE RESEARCH

Innovation exists to complete inherently incomplete markets. In an incomplete market, not all states of nature can be spanned, and as a result, parties are not able to move funds freely across time and space, or to manage risk [5]. Allen and Gale [6] consider a particular form of market incompleteness—in the form of short sales restrictions—as motivation for innovation by parties seeking to share risk. Innovation involving derivatives can improve efficiency by expanding opportunities for risk sharing, by lowering transaction costs and by reducing asymmetric information and agency costs [7].

Flannery [8] provides a review of the evidence on market information in prudential bank supervision; Flannery notes that the weight of evidence supports the proposition that information possessed by analysts and other market participants about the condition of financial firms can be useful. Bank credit contractions can result from losses in bank capital that induces banks to reduce their asset risk [9]. Peretz and Schroedel [10] proposed that a large lesson of financial crisis is that the slackness of United States regulation structure has encouraged financial innovation activities and motivation of investment banking. Various complicated financial innovation products avoid financial regulation on leverage ratios. It not only increased whole risk level of financial markets, but also set some obstacles for regulator monitoring the information about financial innovation, even led to information symmetry of market transactions [11]. Morris and Shin [12] pointed out the traditional financial regulation method based on capital adequate rate only guaranteed financial system of stability within a short-term through recognition financial institution paid capacity. Chen [13] through the game theory analyzes the costs and benefits of the participating subject and their behaviors in the process of securities investment supervision, then gives advices to each subject participates the process so as to strengthen the investment supervision. Li [14] researched on the choice of financial institutions capital leverage in different regulations and how the financial regulatory system influenced the behavior of financial institutions and financial stability. Zhang and Zhang [15] explain external social effects of financial innovation and regulation based on improved game model. Therefore, the effect of institutional change will not be limited to private sector financial institutions, but will also encompass public-sector government institutions that are associated with the financial markets. Yan [16] discussed the global financial crisis made all countries begin to take a new look at the relationship between financial innovation and financial supervision. Guo and Fang [4] analyzed the behavior of company and the bank or other discount capital provider according to the evolutionary game theory. In the end, normative research results and suggestions are given regarding policy-making in CP market supervision. Tufano [17] analyses of tax rules, regulation and innovation; studies of financial an

overly generous term. Owen, Goldwasser, Choate and Blitz [18] proposed management innovation alliance framework, by the cooperative innovation of enterprise alliance to improve the success rate of innovation.

3. GAME MODEL

Game theory has been widely used in research work in the field of biological evaluation, it is also referred to as evolutionary game, and the game research equilibrium strategy is called evolutionary stable strategy (ESS).

3.1 Model Assumptions

Assumption 1: There are two players in the model: a financial institutions and a regulator with bounded rationality. All participants did not know each other's choice before they decided, so the information is incomplete.

Assumption 2: Financial institutions have to transmit information to innovation. They have two options: legal innovation with the probability or illegal innovation with the probability aid.

Assumption 3: Regulators have two options: deregulation with probability or strict supervision with the probability.

Assumption 4: Payoffs

Case 1: When financial institutions choose illegal innovation and Regulators choose deregulation, the payoffs of financial institution and regulator are F and R, that is (F, R).

Case 2: When financial institutions use legal innovation and regulators choose deregulation, the payoffs is F + B. B is due innovation to generated the increase in revenue. Under the legal innovation, due to market order is destroyed and bring lost cost is denoted as L1, the payoffs of regulators is R- L1.

Case 3: When financial institutions choose illegal innovation and regulators choose strict supervision, the payoffs of is R – C, where C is regulatory cost.

Case 4: When financial institutions choose legal innovation and regulators choose strict supervision, the payoff is F + B – L2, where L2 is regulatory lost cost.

Fig. 1 is the Dynamic game model with incomplete information. Table 1 is the payoffs of financial institutions and regulators.

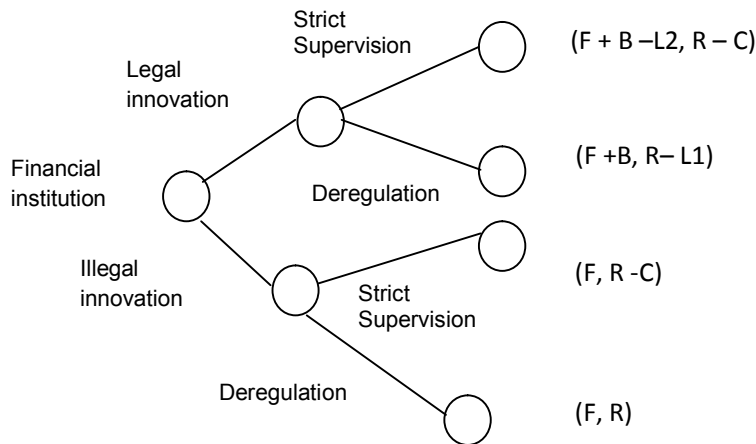


Fig. 1. Dynamic game model with incomplete information

Table 1. The payoffs of financial institutions and regulators

		Financial institutions	
		Legal innovation (x)	Illegal innovation (1-x)
Regulators	Strict supervision (y)	(F +B -L2, R -C)	(F, R -C)
	Deregulation (1-y)	(F +B, R- L1)	(F, R)

3.2 The Equilibrium Analysis of Game

If financial institutions always choose the legal innovation, the regulators will not choose the strict supervision; if the regulators imply deregulation, with a view of maximizing interest, financial institutions will choose illegal innovations. Regulator's task is making (deregulation, illegal) not be a pure strategy Nash equilibrium of the game, otherwise financial system will be destroyed, regulators' all efforts will be in vain. Therefore, the following conditions must be at the same time: (1) for the financial institutions, under strict supervision conditions, their earnings of legal innovation is better illegal one; (2) for regulators, there is illegal innovation, the payoff of strict monitoring is more than deregulation [11].

$$R - C > R - L1 \tag{1}$$

$$R > R - C \tag{2}$$

In Eq. (1), the game equilibrium is (Legal innovation, Regulation), when $C < L1$. The game equilibrium is (Legal innovation, Deregulation), when $C > L1$.

In eq. (2), the game equilibrium is (Illegal innovation, deregulation).

$$F + B - L2 > F + B \tag{3}$$

In Eq. (3), the game equilibrium is (Regulation, Legal innovation), when $B > L2$. The game equilibrium is (Regulation, Illegal innovation), when $B < L2$.

Regulators choose strict regulation with probabilities (y) and deregulation with the probability of (1 - y). Financial institution carry out illegal innovation with probability (x) and legal innovation with the probability (1- x).

There is a mixed strategy Nash equilibrium of this game.

$$x (F + B - L2) + (1 - x) F = x(B - L2) + F \tag{4}$$

$$F(x, y) = \frac{dx}{dt} = (x(U_1 - U)) = x(1-x)(U_1 - U_2) = x(1-x)(L1y - L1) \tag{14}$$

According the stability theorem for differential equation [19,20] only $F(x, y) < 0$, evolutionary strategy has relatively good stability. Let x^* be a financial institutions stable. Let $F(x, y) = 0$, then $x_1^* = 0$, $x_2^* = 1$ or $y_3^* = 1$ is the stable state for replication dynamic equation.

It derives the regulation institution replication dynamic equation based on (11), (12), and (13): Set

$$y(R - C) + (1 - y) (R - L1) = y(L1 - C) + (R - L1) \tag{5}$$

Solving the equations, we get:

$$x = F / (L2 - B) \tag{6}$$

$$y = (R - L1) / (C - L1) \tag{7}$$

From (6), since $0 < x < 1$, then we get $F < (L2 - B)$. From (7), since $0 < y < 1$, then we get $(R - L1) < (C - L1)$. In reality, the two factors L1 and L2 can be adjusted and changed by the subjective will of regulators; this provides the theoretical basis of the regulatory mechanism design. When the income gap between the illegal and legal innovation grows, the difference would stimulate financial to carry out the illegal innovation, then the regulator should increase the probability of strict supervision.

4. FINANCIAL INNOVATION AND REGULATION EVOLUTIONARY GAM

4.1 The Dynamic Model of Financial Institution and Regulation

Use U_1 and U_2 as the expected return of legal innovation and illegal innovation respectively, total average expected return for the financial institution is U , U_1 , U_2 and U is given as follows:

$$U_1 = y(R - C) + (1-y) (R - L1) \tag{8}$$

$$U_2 = y(R - C) + (1-y) R \tag{9}$$

$$U = x U_1 + (1 - x) U_2 = U_2 + (U_1 - U_2) x \tag{10}$$

Use V_1 and V_2 as the expected return of strict supervision and Deregulation respectively, total average expected return for the financial institution is V , V_1 , V_2 and V is given as follows:

$$V_1 = x (F + B - L2) + (1-x) (F + B) \tag{11}$$

$$V_2 = x F + (1-x) F \tag{12}$$

$$V = y V_1 + (1 - y) V_2 = V_2 + (V_1 - V_2) y \tag{13}$$

It derives the financial institution replication dynamic equation based on (8), (9), and (10): Set

$$G(x, y) = \frac{dy}{dt} = (y(V_1 - V)) = y(1 - y)(V_1 - V_2) = y(1 - y)(B - L2x) \tag{15}$$

Let y^* be a financial institutions stable. Let $G(x, y) = 0$, then $y_1^* = 0$, $y_2^* = 1$ or $x_3^* = B/L2$ is the stable state for replication dynamic equation.

There have five stable equilibrium points in financial innovation and regulation model: O (0, 0), A (0, 1), C (1, 0), B (1, 1) and D (B/L2, 1).

4.2 Evolutionary Stable Strategy of the Solution

If $x \neq B/L2$, they need to solve the case when $G(x, y) = \frac{dy}{dt} < 0$ to determine the trend of the groups.

$G(x, y)$ Approach to 1 for ESS, when $x > B/L2$. $G(x, y)$ Approach to 0 for ESS, when $x < B/L2$. The three phase diagrams represent the dynamic trend of the three states of x and its stability.

Fig. 2 is Evolutionary game analysis game dynamic trend and stability diagram. Fig. 3 is Evolutionary game analysis game dynamic trend and stability diagram.

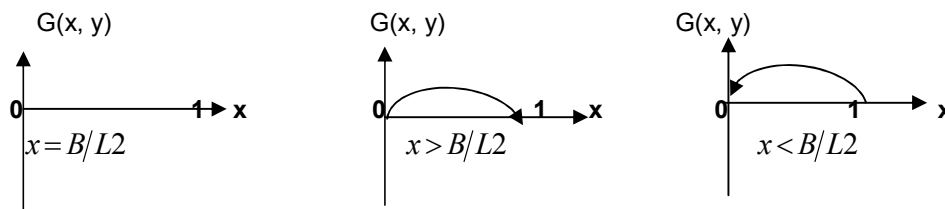


Fig. 2. Evolutionary game analysis game dynamic trend and stability diagram

It can put on the relationship of replication dynamic changing in the Cartesian coordinates as following.

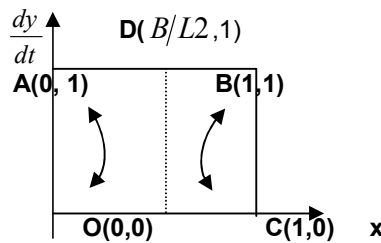


Fig. 3. Evolution game analysis game party type proportional trend diagram

5. DISCUSSION AND CONCLUSION

Financial innovation and financial supervision promote each other mutually. Financial supervision is the motive of financial innovation and financial innovation furthers the improvement of financial regulatory system. However, it very clears such a deduction of trade-off between regulation and the opportunity for illegal innovation. Owen, Goldwasser, Choate and Blitz [18] proposed management innovation alliance framework. It is shown that, if the corporation's

additional revenue of breaking the contract is greater than the excess returns of continuous cooperative innovation, the strategy choice of corporation will depend on the probability of the other corporation' strategy, but cooperative innovation will eventually terminate, because of one corporation' breaking the contract. If financial institution innovation regulation mainly depends on the financial information reveal and accounting information, it did not from the unified supervision information sharing mechanism in the supervision and regulation of financial

products trading. Therefore, the wide variety of financial product innovation, the extensive application of information technology and artificial intelligence technology improve the level of the supervision work [11].

The results of this model: (1) In regulation mechanisms, regulatory costs and the financial institutions' illegal innovation's lost cost will affect the probability of financial institutions innovation. (2) In financial mechanisms, financial institutions innovation brought excess return in violations, which in turn affects the probability of regulator to choice supervision.

It discuss variable x , the express $B/L2$, it can be seen as a critical value on the market in regulatory authorities and financial institutions. This threshold by B and $L2$ two factors, which means that innovation to generated the increase in revenue, and the regulatory lost cost. When the $B/L2$ value decreased, comparing with the original rational expectation value x , the value of $G(x, y)$ becomes positive, so Regulators must increase the proportion of supervision.

According to the game analysis of financial institutions and regulators, it makes the following recommendations:

1. It must be strengthen the effective combination between the market restriction and supervision. Utilize regulators punishment mechanism reasonably, establish prevention mechanism.
2. The financial supervision system of financial derivatives still exist many imperfections. The construction and design supervision system, it should fully use the experience of financial derivatives regulation system like United States, such as strengthens financial derivatives regulatory system design. It is necessary for regulations to standardize information collection forms and requirements, take the various types of transaction information and monitoring into supervision information platform and adjust regulation system in the regulatory process timely.
3. The financial system must be established and improved in innovation to ensure financial information is truthful, accurate and complete, enhance the transparency of information. Form the long term perspective, cooperative relationship between innovation institutions and regulatory should be established.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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