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A dynamic game in regulations of commercial banks

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This paper constructs a three-stage dynamic game model to study the strategy selections in a game of commercial banks and regulatory authorities. We first find out payoffs for each combination of strategies in the game, and then analyze the effects of different factors on the strategy selections of regulatory authorities and commercial banks. We conclude that (1) regulatory authorities can increase revenue by raising the probability of penalizing or the amount of fine on violation behaviors of commercial banks; (2) commercial banks tend to violate rules if the probability of being penalized or the amount of fine is low; (3) extra revenue is the main reason for commercial banks to violate rules; (4) high rewards of obeying rules can weaken commercial banks’ tendency to violate rules.

Key words: Dynamic game, commercial banks, regulatory authorities, strategy selection.

INTRODUCTION

Finance is the core of any economy. In any financial system commercial banks usually play an important role. Commercial banks focus on currency management that provides financing services for the development of economy. On the other hand, commercial banks are the transmission hub of monetary policy and the efficiency of central bank’s policy adjustments relies heavily on behaviors of commercial banks.

In some developing countries, property right of commercial banks is experiencing deep changes. For example, in China, changes of property right make commercial banks be more and more independently involved in market activities. Flexible system of property right improves commercial banks’ operational efficiency and their ability of risk management. However, it is also necessary for regulatory authorities to set a higher level of financial regulation than ever. One reason is that commercial banks’ daily business activities will sometimes cause the underestimation of risks in the process of pursuing profit and then might threaten the safety and stability of entire financial system. Another reason is that differences between objectives of commercial banks and objectives of monetary policy may affect the effectiveness of monetary policy. Therefore, how to strengthen financial regulations becomes a pressing issue in the perspective of changes of commercial banks’ property right.

Economic development is inseparable from financial support. As the most important component of the financial system, safe and stable operations of commercial banks are tightly related to the economic development. However, banking industry is one of the most vulnerable parts in the whole financial system. Banking industry is usually doing business with a very high asset-liability ratio although it reaches the requirement of capital adequacy ratio. Experience of past financial crisis shows that banking industry is always the first to be affected and then suffers heavy losses. Therefore, regulations of commercial banks, especially when commercial banks are in the process of property right change, become a theoretical and practical focus of research.

Thakor (1991) apply the game theory to study financial regulation in financial innovations and show that financial regulation is a repeated game between regulatory authorities and financial institutions, where regulations make commercial banks innovate frequently and financial innovations make regulatory authorities adjust regulation policies. Peek and Rosengren (1996) make an empirical study on the relation between financial regulations and actions of banks and find that with the increased flexibility of property rights system commercial banks will quickly adjust their portfolio in response to the impact of declining capital caused by financial regulations.

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Besanko and Kanatas (1996) develop an econometric model to study financial regulations under the condition of separation of commercial bank’s operation right and property right and the empirical results show that regulatory effects differ among commercial banks with different property right structures. Borio (2003) defines, compares and contrasts the macro- and micro-prudential dimensions that inevitably coexist in financial regulatory and supervisory arrangements, examines the nature of financial instability against this background and draws conclusions about the broad outline of desirable policy efforts. Allen and Gale (2004) make comparisons of banking industries of different countries and find that the stability of banking system is positively correlated to the concentration degree of commercial banks.

Angkinand (2009) analyzes the relationship between banking regulation and the severity of banking crises measured in terms of the magnitude of output loss, and the empirical results show that countries that provide comprehensive deposit insurance coverage and enforce strict bank capital adequacy requirements experience a smaller output cost of crises.

Existing literature mainly focuses on the regulations of commercial banks from the perspective of regulatory authorities. In this paper, we will apply a dynamic game model to study the strategy selections from the perspective of both regulatory authorities and commercial banks. We first find out payoffs of each combination of strategies and then analyze the effects of factors that will affect the strategy selections.

A THREE-STAGE DYNAMIC GAME MODEL

Players

Players of the game are commercial banks and regulatory authorities. In an environment of market economy, commercial banks and regulatory authorities will select strategies according to the following two aspects: (1) Information asymmetry exists between commercial banks and regulatory authorities and thus their strategies will be selected in the presence of information asymmetry; (2) As rational economic persons, both commercial banks and regulatory authorities obey the principle of revenue maximization.

Stages

In order to maintain the stability of social economy and the efficiency of financial market, regulatory authorities may have to make policy adjustments. According to the policy adjustments, commercial banks will choose to obey rules or violate rules. If commercial banks choose to violate rules, regulatory authorities will decide to penalize or not. Therefore, a complete game can be separated into 3 stages:

Stage 1: Regulatory authorities choose to make policy adjustments or not. Assume that $\alpha$ is the probability of implementing adjustments and then $1-\alpha$ is the probability of no adjustments.

Stage 2: Commercial banks choose to obey rules or violate rules. Assume that the probability of violating rules is $\beta$ and then the probability of obeying rules is $1-\beta$.

Stage 3: Regulatory authorities choose to penalize commercial banks with violation behaviors or not. Assuming that the probability of penalizing is $\gamma$ then the probability of not penalizing is $1-\gamma$.

Payoffs

Following the three stages described in previously, we analyze the payoffs for each combination of strategies of regulatory authorities and commercial banks.

1. Regulatory authorities choose not to make policy adjustments.
   (a) Commercial banks obey rules. If regulatory authorities do not adjust policy and commercial banks obey rules, then both players stay in the original equilibrium. There is no extra cost for regulatory authorities and assume the payoff is $R_i$. Commercial banks do not need to pay extra cost either and assume the payoff is $R_i$. Therefore, the payoff of regulatory authorities and commercial banks is $(R_i, R_i)$.
   (b) Commercial banks violate rules and regulatory authorities choose not to penalize. Let $\Delta R$ denote the extra revenue of commercial banks’ violation behaviors. Violation behaviors of commercial banks will bring negative effects on financial market, denoted by $B$, which should be deducted from the payoff of regulatory authorities. Therefore, the payoff of regulatory authorities and commercial banks is $(R_i - B, R_i + \Delta R)$.
   (c) Commercial banks violate rules and regulatory authorities choose to penalize. If commercial banks violate rules and are then penalized, regulatory authorities will confiscate their extra revenue $\Delta R$ and impose a fine of $P$, while the negative impact $B$ of non-compliance behaviors still exists. Therefore, the payoff of regulatory authorities is $R_i + \Delta R + P - B$. Reputation of commercial banks is reduced when they are penalized, which results in a reduced revenue denoted by $R_i' (R_i' < R_i)$. The payoff of regulatory authorities and commercial banks is $(R_i + \Delta R + P - B, R_i' - P)$.

2. Regulatory authorities choose to make policy adjustments.
Figure 1. Tree of the game between regulatory authorities and commercial banks.

(a) Commercial banks obey rules. Assume that the cost of adjustments is $C$. Commercial banks will be rewarded $\Delta r$ for their obedience. Therefore, the payoff of regulatory authorities and commercial banks is $(R_i - C - \Delta r, R_i + \Delta r)$.

(b) Commercial banks violate rules and regulatory authorities choose not to penalize. The negative impact of violation behaviors on financial market is $B$, while the extra revenue is $\Delta R$. Therefore, the payoff of regulatory authorities and commercial banks is $(R_i - C - B, R_i + \Delta R)$.

(c) Commercial banks violate rules and regulatory authorities choose to penalize. For regulatory authorities, they will get the extra revenue $\Delta R$ of commercial banks and the fine of $P$, while have to pay the cost of adjustments $C$ and suffer the negative effects of $B$. For commercial banks that are penalized, the revenue will be reduced to $R'_i (R'_i < R_i)$. Therefore, the payoff of regulatory authorities and commercial banks is:

$$(R_i + \Delta R + P - C - B, R'_i - P).$$

According to the payoffs and probabilities for each combination of strategies, we plot the game tree in Figure 1 and then we can analyze the effects of different factors on strategy selections of regulatory authorities and commercial banks from the perspective of revenue maximization.

### STRATEGY SELECTIONS

Considering the corresponding revenues and costs, both regulatory authorities and commercial banks will select strategies according to the principles of revenue maximization.

#### Strategies of regulatory authorities

If commercial banks violate rules and regulatory authorities choose to penalize, then the expected payoff of regulatory authorities is

$$V_i = \alpha \beta \gamma (R_i + \Delta R + P - C - B) + (1 - \alpha) \beta \gamma (R_i + \Delta R + P - B) = \beta \gamma (R_i + \Delta R + P - B - \alpha C)$$

(1)

If commercial banks violate rules and regulatory authorities choose not to penalize, then the
expected payoff of regulatory authorities is

\[ V'_r = a\beta(1 - \gamma)(R_r - C - B) + (1 - a)\beta(1 - \gamma)(R_r - B) = \beta(1 - \gamma)(R_r - B - \alpha C) \]

(2)

If commercial banks violate rules, the opportunity revenue of regulatory authorities by choosing to penalize or not is

\[ \Delta V_i = V_i - V'_i = \beta\gamma(R_i + \Delta R + P - B - \alpha C) - \beta(1 - \gamma)(R_i - B - \alpha C) \]

(3)

**Effect of the probability of penalizing** \( \gamma \)

Solving \( \Delta V_i = 0 \) for the probability of penalizing \( \gamma \), we have

\[ \gamma^* = \frac{R_i - B - \alpha C}{2R_i + \Delta R + P - 2B - 2\alpha C} \]

And the derivative of \( \Delta V_i \) with respect to \( \gamma \)

\[ \frac{\partial \Delta V_i}{\partial \gamma} = \beta(2R_i + \Delta R + P - 2B - 2\alpha C) - \beta(1 - \gamma)(R_i - B - \alpha C) > 0 \]

Since \( R_i - B - C \) is the payoff of regulatory authorities when commercial banks violate rules and regulatory authorities choose not to penalize. Therefore, if \( \gamma > \gamma^* \) then \( \Delta V_i > 0 \), otherwise \( \Delta V_i < 0 \). Therefore, in order to have a positive opportunity revenue, regulatory authorities tend to increase the probability of penalizing.

**Effect of the fine** \( P \)

Solving \( \Delta V_i = 0 \) for the amount of fine \( P \), we have

\[ \Delta V_i = V_i - V'_i = \beta\gamma(R_i + \Delta R + P - B - \alpha C) - \beta(1 - \gamma)(R_i - B - \alpha C) \]

(6)

\[ p^*_i = \frac{(1 - 2\gamma)(R_i - B - \alpha C) - \Delta R}{\gamma} \]

And the derivative of \( \Delta V_i \) with respect to \( P \)

\[ \frac{\partial \Delta V_i}{\partial P} = \beta \gamma > 0 \]

This means if \( P > p^*_i \) then \( \Delta V_i > 0 \), otherwise \( \Delta V_i < 0 \). In order to have a positive opportunity revenue, regulatory authorities tend to increase the amount of fine.

In summary, regulatory authorities have a tendency to increase the probability of penalizing or the amount of fine in order to increase their opportunity revenue and improve their prestige.

**Strategies of commercial banks**

As rational economic persons, commercial banks select strategies to achieve the maximization of revenue. If commercial banks violate rules, the expected payoff is

\[ V'_r = \gamma(R'_r - P) + (1 - \gamma)(R_r + \Delta R) \]

(4)

The expected payoff of commercial banks when they obey rules is:

\[ V_r = (1 - \beta)R_r + \alpha(1 - \beta)\Delta r \]

(5)

Therefore, the opportunity revenue of choosing to obey rules or violate rules is

\[ \Delta V_r = V'_r - V_r = \beta\gamma(R'_r - P) + (1 - \gamma)(R_r + \Delta R) - (1 - \beta)R_r - \alpha(1 - \beta)\Delta r \]

(6)

\[ P_0 = R'_r - \frac{(1 - 2\beta + \gamma)(R_r + \alpha(1 - \beta)\Delta r - \beta(1 - \gamma)\Delta R)}{\beta \gamma} \]

And the first order derivative of \( \Delta V_r \) with respect to \( P \) is

\[ \frac{\partial \Delta V_r}{\partial P} = -\beta \gamma \leq 0 \]

Which implies that if \( P < P_0 \) then \( \Delta V_r > 0 \), otherwise
\( \Delta V_2 < 0 \)

Solving \( \frac{\partial \Delta V_2}{\partial \beta} = 0 \) for \( P \), we have

\[
P^* = \frac{1 - \gamma)\Delta R + 2R_2 + \alpha \Delta r - (R_2 - R'_2)}{\gamma}
\]

If \( P > P^* \) then \( \frac{\partial \Delta V_2}{\partial \beta} < 0 \) and if \( P < P^* \) then \( \frac{\partial \Delta V_2}{\partial \beta} > 0 \).

Comparing \( P^* \) and \( P_0 \) we have,

that is \( P_2 < P_0 \). With different amounts of fine, there are three possible cases as follows:

A. \( P < P_2 < P^* \). In this case \( \Delta V_2 > 0 \) and \( \frac{\partial \Delta V_2}{\partial \beta} > 0 \). The opportunity revenue of commercial banks increases as the probability of violating rules increases, meanwhile the opportunity revenue is always positive. Therefore, commercial banks have a strong motivation to violate rules and have a tendency to increase the probability of violating rules.

\[
P_0 - P^* = \frac{-R_2 - \alpha \Delta r}{\beta \gamma} < 0
\]

B. \( P_2 < P < P^* \). In this case \( \Delta V_2 < 0 \) and \( \frac{\partial \Delta V_2}{\partial \beta} > 0 \). Although the opportunity revenue of commercial banks increases as the probability of violating rules increases, commercial banks will choose not to violate rules since the opportunity revenue is negative.

C. \( P_0 < P^* < P \). In this case \( \Delta V_2 < 0 \) and \( \frac{\partial \Delta V_2}{\partial \beta} < 0 \). Commercial banks choose to obey rules.

**Effect of the probability of penalizing \( \gamma \)**

Solving \( \Delta V_2 = 0 \) for \( \gamma \) yields

\[
\gamma_0 = \frac{\beta \Delta R - (1 - 2\beta)R_2 - \alpha(1 - \beta)\Delta r}{\beta(R_2 - R'_2 + P + \Delta R)}
\]

And the first order derivative is

\[
\frac{\partial \Delta V_2}{\partial \gamma} = \beta \left[ \frac{(R'_2 - P) - (R_2 + \Delta R)}{\Delta R} \right] \leq 0
\]

Which means if \( \gamma < \gamma_0 \) then \( \Delta V_2 > 0 \), otherwise \( \Delta V_2 < 0 \).

\[
\frac{\partial \Delta V_2}{\partial \gamma} = 0 \text{ for } \gamma, \text{ we have}
\]

\[
\gamma' = \frac{2R_2 + \Delta R + \alpha \Delta r}{R_2 - R'_2 + P + \Delta R}
\]

If \( \gamma > \gamma' \) then \( \frac{\partial \Delta V_2}{\partial \beta} < 0 \), otherwise \( \frac{\partial \Delta V_2}{\partial \beta} > 0 \).

\[
\gamma_0 - \gamma' = \frac{-R_2 - \alpha \Delta r}{\beta(R_2 - R'_2 + P + \Delta R)} < 0
\]

Since \( \gamma_0 < \gamma' \), we have the following three cases.

A. \( \gamma < \gamma_0 < \gamma' \). In this case \( \Delta V_2 > 0 \) and \( \frac{\partial \Delta V_2}{\partial \beta} > 0 \). The opportunity revenue is positive and increases as the probability of violating rules increases. Therefore, commercial banks have strong motivations to violate rules and also tend to increase the probability of violating rules in order to increase the opportunity revenue.

B. \( \gamma_0 < \gamma < \gamma' \). In this case \( \Delta V_2 < 0 \) and \( \frac{\partial \Delta V_2}{\partial \beta} > 0 \). Since the opportunity revenue is negative, commercial banks will not tend to violate rules, although the opportunity revenue increases as the probability of violating rules increases.

C. \( \gamma_0 < \gamma < \gamma' \). In this case \( \Delta V_2 < 0 \) and \( \frac{\partial \Delta V_2}{\partial \beta} < 0 \). Commercial banks choose to obey rules.

**Effect of the extra revenue of non-compliance \( \Delta R \)**

Solving \( \Delta V_2 = 0 \) for \( \Delta R \), we get

\[
\Delta R_0 = \frac{(1 - 2\beta + \beta \gamma)R_2 + \alpha(1 - \beta)\Delta r + \beta \gamma(P - R'_2)}{\beta(1 - \gamma)}
\]

And the first order derivative of \( \Delta V_2 \) with respect to \( \Delta R \) is

\[
\frac{\partial \Delta V_2}{\partial \Delta R} = 1 - \gamma \geq 0
\]

Which implies that if \( \Delta R < \Delta R_0 \), then \( \Delta V_2 < 0 \), otherwise \( \Delta V_2 > 0 \).
Solving $\frac{\partial \Delta V}{\partial \beta} = 0$ for $\Delta R$, we have

$$\Delta R^* = \frac{\gamma (R_i - R_i') - 2R_i - \alpha \Delta r}{1 - \gamma}$$

If $\Delta R > \Delta R^*$ we will have $\frac{\partial \Delta V_i}{\partial \beta} > 0$, otherwise $\frac{\partial \Delta V_i}{\partial \beta} < 0$.

Furthermore, we have $\Delta R_0 - \Delta R^* = \frac{R_i + \alpha \Delta r}{\beta (1 - \gamma)} > 0$, that is, $\Delta R_0 > \Delta R^*$. There are three cases according to different values of $\Delta R$.

A. $\Delta R < \Delta R^* < \Delta R_0$. In this case $\Delta V_i < 0$ and $\frac{\partial \Delta V_i}{\partial \beta} < 0$, which implies that the opportunity revenue of commercial banks is negative and it decreases as the probability of violating rules increases. Therefore, commercial banks choose to violate rules.

B. $\Delta R^* < \Delta R < \Delta R_0$. In this case $\Delta V_i < 0$ and $\frac{\partial \Delta V_i}{\partial \beta} > 0$. Although the opportunity revenue of commercial banks increases as the probability of violating rules increases, but the opportunity revenue is negative, commercial banks will choose to obey rules.

C. $\Delta R^* < \Delta R_0 < \Delta R$. In this case $\Delta V_i > 0$ and $\frac{\partial \Delta V_i}{\partial \beta} > 0$. The opportunity revenue of commercial banks increases as the probability of violating rules increases and $\Delta V_i$ is positive. Therefore, commercial banks have strong motivations to violate rules and also have a tendency to increase the probability of violating rules.

**Effect of the reward of compliance $\Delta r$**

Solving $\Delta V_i = 0$ for $\Delta r$ yields

$$\Delta r_0 = \frac{\beta \gamma (R_i - P) + (2\beta - \beta \gamma - 1)R_i + \beta (1 - \gamma) \Delta R}{\alpha (1 - \beta)}$$

And the first order derivative of $\Delta V_i$ with respect to $\Delta r$ is

$$\frac{\partial \Delta V_i}{\partial \Delta r} = -\alpha (1 - \beta) \leq 0$$

Therefore, if $\Delta r > \Delta r_0$ then $\Delta V_i < 0$, otherwise $\Delta V_i > 0$.

Solving $\frac{\partial \Delta V_i}{\partial \beta} = 0$ for $\Delta r$, we get

$$\Delta r^* = \frac{\gamma (P - R_i') - (2 - \gamma)R_i - (1 - \gamma)\Delta R}{\alpha}$$

If $\Delta r > \Delta r^*$ then $\frac{\partial \Delta V_i}{\partial \beta} < 0$, otherwise $\frac{\partial \Delta V_i}{\partial \beta} > 0$. Comparing $\Delta r$ and $\Delta r_0$, we have:

$$\Delta r_0 - \Delta r^* = \frac{-\gamma (P - R_i') + (1 - \gamma)R_i + (1 - \gamma)\Delta R}{\alpha (1 - \beta)}$$

i. If $P < R_i' + \frac{(1 - \gamma)(R_i + \Delta R)}{\gamma}$, then $\Delta r_0 > \Delta r^*$.

A. $\Delta r < \Delta r^* < \Delta r_0$. In this case $\Delta V_i > 0$ and $\frac{\partial \Delta V_i}{\partial \beta} > 0$. The opportunity revenue of commercial banks increases as the probability of violating rules increases and $\Delta V_i$ is positive, which results in intensive motivations of commercial banks to violate rules and also the tendency to increase the probability of violating rules.

B. $\Delta r^* < \Delta r < \Delta r_0$. In this case $\Delta V_i > 0$ and $\frac{\partial \Delta V_i}{\partial \beta} < 0$. The opportunity revenue is positive and therefore commercial banks have motivations to violate rules. However, the desire of violating rules is not strong since the opportunity revenue decreases as the probability of violating rules increases.

C. $\Delta r^* < \Delta r_0 < \Delta r$. In this case $\Delta V_i < 0$ and $\frac{\partial \Delta V_i}{\partial \beta} < 0$, which implies that commercial banks will choose to obey rules.

ii. If $P > R_i' + \frac{(1 - \gamma)(R_i + \Delta R)}{\gamma}$, then $\Delta r_0 < \Delta r^*$.

$\Delta r < \Delta r_0 < \Delta r^*$. In this case $\Delta V_i > 0$ and $\frac{\partial \Delta V_i}{\partial \beta} > 0$. The opportunity revenue of commercial banks increases as the probability of violating rules increases and $\Delta V_i$ is positive. Therefore, commercial banks will not choose to violate rules.

$\Delta r_0 < \Delta r < \Delta r^*$. In this case $\Delta V_i < 0$ and $\frac{\partial \Delta V_i}{\partial \beta} < 0$, which implies that commercial banks will not choose to violate rules.
CONCLUSIONS

This paper applies a three-stage dynamic game model to analyze the effects of different factors on the strategy selections of commercial banks and regulatory authorities in the game. We have the following conclusions.

1. Regulatory authorities can increase their opportunity revenue by raising the probability of penalizing commercial banks with violating behaviors or increasing the amount of fine.
2. Commercial banks choose to violate rules if the probability of being penalized or the amount of fine is low. When the probability of being penalized or the amount of fine is large enough, commercial banks choose to obey rules because the opportunity revenue will be negative.
3. Commercial banks choose to violate rules if their extra revenue of violating rules is large enough.
4. If regulatory authorities' reward of compliance is large enough, commercial banks choose to obey rules.

Based on the conclusions of this study, future work would be an empirical study on the relations between banking regulations and commercial banks’ behaviors in countries such as China, where the property right of commercials is experiencing changes. The empirical study will focus on the effects of factors found in this paper on revenues of commercial banks.

REFERENCES