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An Approach to Explain Bank Runs with Game Theory

Abstract

This paper presents an approach to understand the bank runs with game theory. In the model, each player decides if they withdraw their deposit from the bank and loose accumulated interest or leave the deposit in the bank risking losing the deposit partially or completely. The model considers interest rates, transaction fees, and deposit insurance. The aim of the contribution is to analyse the root cause of bank runs and investigate the impact of deposit insurance on the depositors' withdrawal strategies. Within a dynamic game with incomplete information, a playoff matrix for players is build and the results are analyzed. The results show that there two Bayesian Nash equilibrium and two strategies that can be considered as optimal in the game without deposit insurance which leads to a bank run. On the other hand, with deposit insurance introduced in the game, the optimal strategy is to keep the deposits in the bank which minimizes probability of bank runs.

Key words

Bank run, game theory, dynamic game of incomplete information, Diamond-Dybvig model

JEL Classification

C72, C73

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Introduction

Bank runs are a phenomenon that can have devastating consequences for the economy. They occur when a large number of depositors withdraw their money from a bank over a short period of time, fearing that the bank is about to fail. This is a self-fulfilling prophecy, since no bank is able to pay off all its obligations immediately (Arifovic et al., 2013).

Bank runs are not new and can be caused by a variety of factors. They have occurred throughout history, and they have been especially common during periods of financial crisis. For example, the Great Depression of the 1930s was preceded by a wave of bank runs.

Similarly, the 2008 financial crisis was accompanied by a number of bank runs, including the failure of Lehman Brothers and the near-collapse of AIG. In recent years, there have been a number of high-profile bank runs in the Czech Republic and the United States. In 2022, a bank run on Sberbank in the Czech Republic was triggered by the Russian invasion of Ukraine. In 2023, two bank runs on Silicon Valley Bank and Signature Bank in the Unites States leaded to their failure.

Bank runs can have a significant impact on the economy. When depositors withdraw their money from banks, banks have less money to lend to businesses and consumers. This can lead to a decline in investment and economic growth. Bank runs can also damage confidence in the banking system, which can make it more difficult for banks to borrow money and make loans.

This article explores the phenomenon of bank runs in more detail. It discusses the causes of bank runs with the help of game theory, providing explanations on the depositors' behaviour. The aim of the contribution is to analyse the root cause of bank runs and investigate the impact of deposit insurance on the depositors' withdrawal strategies.

1 Bank Runs

Bank runs occur when a large number of depositors withdraw their money from a bank over a short period of time even if all depositors are rational and fully informed about the bank's financial condition. This was first shown by Douglas Diamond and Philip Dybvig (Diamond a Dybvig, 1983), who presented bank runs as a coordination problem among depositors: each depositor has an incentive to withdraw their money early, before other depositors do, in order to avoid losing their money if the bank fails. This is a self-fulfilling prophecy, even if the bank is solvent. In recent years, more sophisticated theories of bank runs were developed that showed that bank runs can be more likely to occur when depositors have heterogeneous information about the bank's solvency (Allen a Gale, 1998).

The fundamental view of bank runs, on the other hand, sees them as a result of depositors' rational assessment of the bank's solvency. In other words, bank runs occur because depositors believe that the bank is actually insolvent and that they are likely to lose their money if they do not withdraw it immediately. The fundamental view is most famously associated with the work of Xavier Freixas, who argued that bank runs were more likely to occur in countries with weak banking systems and poor regulatory oversight (Xavier Freixas et al., 2000). In recent years, bank runs were caused by both coordination problems and concerns about the bank's solvency.

There are a number of policies that can be used to prevent bank runs. Deposit insurance guarantees depositors up to a certain amount of their money in the event of a bank failure. This can help to reduce depositors' incentives to withdraw their money in the event of a bank run. Another approach to prevent bank runs is capital requirements to hold a certain amount of capital in reserve (Shakina 2019). This helps to protect banks from insolvency and makes them less vulnerable to bank runs. In this article, the major focus is on deposit insurance as a policy to minimize probability of bank runs.

2 Game Theory Model

A basic game model for bank runs was introduced by Diamond and Dybvig in 1992, in which two investors had deposited the amount of D each to a bank. The bank has reinvested the amount of 2D to a long-term project with expected pay-out of 2R to investors in the end of the project, where R > D. In case any of investors withdraw their deposits before the project ends, the bank is required to sell its investments for 2r, where D > r > D/2, due to a penalty. In the model, there are two periods of time when the depositors can withdraw from the bank: period 1 is considered as withdrawal before the project ends, and period 2 is after the project is complete (Lu, 2023).

During period 1, each depositor decides if they want to keep investing or get their amount back. Thus, if one investor makes a withdrawal decision, then:

1. bank sells its investment for 2r;
2. this investor receives amount of D;
3. another investor gets amount of 2r – D;
4. the game ends.

If both investors decide to withdraw, each investor gets amount of r and the game ends. And finally, if both investors keep their deposits in bank, then the project ends, and investors make their decisions at the period 2. Here, if one investor withdraws their deposit, they get amount of 2R – D, and the other one gets only D back. If both investors make the same decision either to get their investment back, or keep in the back, both of them get amount of R (Sun 2023). Since the model doesn't assume any of discounting, the payment matrix can be presented as in the table 1, where R > D > r > 2r – D.

Table No. 1: Payment matrix for standard game

		Investor 2	
		Withdraw deposit	Keep invested
Investor 1	Withdraw deposit	(r,r)	(D, 2r – D)
	Keep invested	(2r – D,D)	(R,R)

Source: Gibbons, 1992, p. 75

The game has two Nash equilibria when both depositors either withdraw or keep deposits invested. The first equilibria, when the depositors withdraw their investments, is considered as a bank run. Due to the game is considered a dynamic game of imperfect information, both investors don't obtain the information regarding the strategy of other players. Thus, if at least one investor believes that the second one is going to withdraw before at period 1, the best response is to play the strategy "withdraw".

This model doesn't consider discounting and deposit protection implemented in the majority of developed countries. Also, this model of a bank run leaves big space for expert assessment of the values of r and R. To cover this gap a new model is presented in the next chapter.

2.1 Game with deposit rates and fall in the stock index

In this game, there are also two of investors: investor 1 and investor 2, which deposited the amount of D each to a bank. The expected payoff for the investors is D(1 + i) – w at the end of their deposits, where i = deposit rate - inflation rate (i ≥ 0) and w is a bank's withdrawal fee (w ≥ 0). Taking into account statistics of occurrence of bank runs, we can assume that bank run is most likely to happen during financial crises, when the majority of stock indexes are rapidly going down. Thus, if the bank run occurs, the bank is forced to sell its assets at a reduced price with a large discount. If the initial investments are in total 2D, then the discounted price at the period 1 is going to be 2D(1 – f), where f is the magnitude of the fall in the stock index (f > 0). Another parameter for the game is DI, the amount covered by deposit insurance.

In this game, there are also two iterations when the depositors can withdraw from the bank: iterations 1 is considered as withdrawal before the deposit expiration time, and iterations 2 is after. During iterations 1, each depositor decides if they want to keep deposited or get their amount back. Thus, if one investor makes a withdrawal decision, then:

1. bank sells its investment for 2D(1 – f);
2. this investor receives amount of D – w;

3. another investor gets amount of min{DI, 2D(1 – f) – (D – w) – w} = min{DI, D(2 – 2f) – D + w – w} = min{DI, D(2 – 2f – 1)} = min{DI, D(1 – 2f)};

4. the game ends.

Here, D > D – w > D(1 – f) > D(1 – 2f). If both depositors decide to withdraw their deposits, they will get min{DI, D(1 – f) – w} each and the game ends. Otherwise, if both investors decide to keep depositing, the game continues at the stage 2. The payment matrix for the iteration 1 is presented in the table 2.

Table No. 2: Payment matrix at the iteration 1

		Investor 2	
		Withdraw deposit	Keep invested
Investor 1	Withdraw deposit	(min{DI, D(1 – f) – w}, min{DI, D(1 – f) – w})	(D – w, min{DI, D(1 – 2f)})
	Keep invested	(min{DI, D(1 – 2f)}, D – w)	The second iteration

Source: Author's own

At the iteration 2, if both investors decide to keep their deposit, they both will get D(1 + i) – w. If both investors decide to withdraw their deposit, they both will get D(1 – f) each. If only one investor makes a withdrawal decision, they will get D(1 + i) – w, while the other gets min{DI, D(1 – f)}. These options are illustrated as payment matrix in the table 3.

Table No. 3: Payment matrix at the iteration 2

		Investor 2	
		Withdraw deposit	Keep invested
Investor 1	Withdraw deposit	(D(1 – f), D(1 – f))	(D(1 + i) – w, min{DI, D(1 – f)})
	Keep invested	(min{DI, D(1 – f)}, D(1 + i) – w)	(D(1 + i) – w, D(1 + i) – w)

Source: Author's own

Since min{DI, D(1 – f)} ≤ D(1 – f) and D(1 – f)) ≤ D(1 + i) – w the strategy "Withdraw" strongly dominates the "Keep invested" strategy. We can simplify the payment matrixes with 2 iterations into normal game with only 1 iteration, as it is presented in the table 4.

Table No. 4: Summarized payment matrix for the game

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Investor 2</td></tr>
<tr><td>Withdraw deposit</td><td>Keep invested</td></tr>
<tr><td rowspan="2">Investor 1</td><td>Withdraw deposit</td><td>(min{DI, D(1 – f) – w},
min{DI, D(1 – f) – w})</td><td>(D – w,
min{DI, D(1 – 2f)})</td></tr>
<tr><td>Keep invested</td><td>(min{DI, D(1 – 2f)},
D – w)</td><td>(D(1 + i) – w,
D(1 + i) – w)</td></tr>
</table>

Source: Author's own

2.2 Impact of the deposit insurance on the preferred strategy

To analyze this game, let us consider 2 cases: when the deposited amount D equals or less than deposit insurance ($D \leq DI$), and the opposite case $D > DI$.

In the first case, $D(1 – 2f) < D(1 – f) – w < D \leq DI$, the min functions will have the following solutions:

- $\min\{DI, D(1 – f) – w\} = D(1 – f) – w$
- $\min\{DI, D(1 – 2f)\} = D(1 – 2f)$

The payment matrix is presented in table 5 for the case 1.

Table No. 5: Summarized payment matrix with deposited amount less than insurance

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Investor 2</td></tr>
<tr><td>Withdraw deposit</td><td>Keep invested</td></tr>
<tr><td rowspan="2">Investor 1</td><td>Withdraw deposit</td><td>(D(1 – f) – w, D(1 – f) – w)</td><td>(D – w, D(1 – 2f))</td></tr>
<tr><td>Keep invested</td><td>(D(1 – 2f), D – w)</td><td>(D(1 + i) – w,
D(1 + i) – w)</td></tr>
</table>

Source: Author's own

Since $D(1 – 2f) < D(1 – f) – w$ and $D – w < D(1 + i) – w$, we have 2 Nash equilibria: (D(1 – f) – w, D(1 – f) – w) and (D(1 + i) – w, D(1 + i) – w). The first equilibrium is bank run and this strategy is the most likely to choose for any of investors if they believe that other investor is going to withdraw their deposit. But in the second case, when $D > DI$, the payment matrix has values as it is presented in the table 6. Here, the strategy "Keep invested" strongly dominated "withdrawal" strategy. This result shows that if a policy of deposit insurance is implemented, depositors are less likely to participate in withdrawals causing bank runs.

The second conclusion that can be done from the model, that the bigger insurance deposit, the less likely depositors will take out their funds.

Table No. 6: Summarized payment matrix with deposited amount more than insurance

		Investor 2	
		Withdraw deposit	Keep invested
Investor 1	Withdraw deposit	(DI, DI)	(D – w, DI)
	Keep invested	(DI, D – w)	(D(1 + i) – w, D(1 + i) – w)

Source: Author's own

Conclusion

The aim of the contribution is to analyse the root cause of bank runs and investigate the impact of deposit insurance on the depositors' withdrawal strategies. The article investigates the reasons why depositors choose the "withdrawal deposits" strategy over "keep deposited" with the game theory model. It was shown, that the game with two investors has 2 Nash equilibria, one of which is to withdraw funds from the bank. If any of investors believe that the other investor will withdraw their funds from the bank, the best strategy for that investor is to withdraw the funds either. This satiation is considered as ban run. On the other hand, implementing policy of deposit insurance decreases probability for bank that their depositors will withdraw their funds. The bigger insured amount, the less motivation to make a withdrawal decision.

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