Bank Run Model: The Application of Game Theory

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Abstract. The term "bank run" describes the mass withdrawal of funds from a bank by its customers. With cash on hand, the bank might be able to handle the situation. As more consumers pull their money out of the company's bank accounts, the likelihood of the business collapsing increases. Based on this, this paper studies the bank run in game theory. It was found that: within the framework of game theory, this situation might be represented as a "coordination game," the latter being a kind of game with two distinct and stable equilibrium states: If enough people keep their money in the bank, the bank won't be able to default on its responsibilities, thus keeping your money there makes sense. On the other hand, if many customers withdraw their deposits, the bank will collapse, and at that time, it is logical for all of the customers to seek to withdraw their money. To clarify the phenomenon of bank runs, this study will use the Diamond-Dybvig model. This theory holds that a bank's primary function is facilitating long-term loans for investment purposes and short-term deposits. A bank run occurs when too many individuals take their money from a financial institution before the long-term debts are returned.

Keywords: Bank run; game theory; Diamond-Dybvig model.

1. Introduction

1.1 The Definition of Bank Run

When a considerable number of depositors take their money out of a bank all at once because of fear that the financial institution will collapse, this is known as a "bank run." As more people take money from their bank accounts, the banks will eventually deplete their cash reserves and collapse. There have been bank runs throughout history, particularly during the Great Depression and the financial crisis that occurred in 2008-2009.

1.2 Different Types of Bank Runs

In a silent bank run, funds are withdrawn electronically rather than in person. This is because most bank locations need to maintain substantial cash. In truth, most institutions limit how much they store in their vaults daily. These restrictions are set based on need and safety. Additionally, the Federal Reserve Bank imposes institutional cash limits. The available funds are either leased to others or invested in various investment instruments. To fulfill client withdrawal requests, banks must increase their cash position since they typically maintain just a tiny proportion of deposits as cash on hand. A bank may increase its cash by selling assets at far lower prices than if it did not need to sell quickly. The bankruptcy of a bank might result from selling assets at reduced prices. A bank panic occurs when many banks are simultaneously robbed.

1.3 The Risk of Bank Run: Liquidity Risks

"Liquidity" describes the ease with which an asset or security may be bought or sold on the market. This slang term alludes to a rate at which anything may be exchanged for monetary value. Two types of liquidity issues exist. First is market liquidity risk, also known as asset/product risk, and second is finance liquidity risk, also known as cash flow risk.

1.3.1 Funding Liquidity Risk

When determining whether a company can fulfil its obligations, a treasurer's primary concern is financial risk, often known as cash flow liquidity risk. The current ratio (current assets/current liabilities) or the quick ratio is a time-tested indication of the financial liquidity risk of a business. A traditional mitigator resembles a line of credit.

1.3.2 Market Liquidity Risk

Asset illiquidity is a market or asset liquidity-related risk. This refers to the inability to leave a job quickly and without difficulty. For instance, we may possess real estate, but we can only sell it quickly at a "fire sale" price owing to the present status of the market. There is no doubt that the item is valuable, but it’s worth cannot be realized since there are no customers.

2. Diamond-Dybvig model

One of the most well-known models of bank runs and the accompanying financial crises is called the Diamond-Dybvig model. This model demonstrates how the mix of illiquid assets (such as commercial or mortgage loans) and liquid liabilities (immediately withdrawable deposits) at a bank may trigger a self-fulfilling panic among the bank's depositors. The model suggests that an organisation can be unstable if it has both long-term assets and short-term liabilities. According to the research conducted by Diamond and Diwig, business investments typically need current expenditures to achieve future advantages. As a result, they choose loans with longer maturities, often known as less liquid loans. The same reasoning is applicable to private customers looking for financing for major items such as houses or vehicles. It is possible for individual savers, including families and organisations, to have unexpected and unplanned requests for funds due to unforeseen expenditures. Consequently, they demand liquid accounts that provide instant access to deposits (that is, they choose accounts that provide access to short-term deposits) [1].

The function of banks in this hypothetical scenario is to fulfil the role of intermediaries between depositors who prefer checking accounts and borrowers who are interested in long-term loans. When they convert big personal deposits into loans for borrowers, banks often offer their customers an important and valued service. Depositors who are people may need assistance to make these loans on their own since individuals may have an urgent need for their finances. Still, the investments that businesses make may only generate profits in the future. Banks can generate profits by charging higher lending rates than deposit rates because they offer useful services to both parties (long-term loans to companies and liquid accounts to depositors, respectively).

If everyone waits until the withdrawals are finalised, they will each get their original money back, in addition to whatever profit they made. However, if there are an overwhelming number of early withdrawals, the bank will run out of money, and the depositors will still get nothing back. The objective of the experiment was to determine how many early withdrawals the bank could tolerate before it could no longer meet its commitments to the customers who had already deposited money [2]. When circumstances are tough, more depositors take their money out of the bank, which "squeezes" the available liquidity while trying to satisfy extra withdrawal requests.

3. Game Theory Model

3.1 Game Between Banks and Depositors

There are two sorts of banks susceptible to a bank run. Both are commercial banks, but one is far stronger than the other. Commercial banks with a larger market share are more numerous than those with a smaller market share. Customers may pick between two options. The depositor is permitted to withdraw their funds. Likewise, financial institutions might react either favorably or adversely [3].

The game process for a powerful commercial bank is shown in Table 1 ($A>B>C$ with A, B, and C <0). If a depositor chooses to withdraw their funds while applying the underlying method, the bank may react favorably or badly, but the incentive remains the same. The bank will pick a negative answer if depositors do not withdraw their funds. To maximize their return, the depositor will opt not to withdraw their funds when the bank responds favorably. Depositors could withdraw their cash if the financial institution decides to take a negative stance. Thus, the Nash equilibrium for this game is for depositors not to withdraw their funds and for the bank to choose a negative reaction.

Table 1. Game matrix

	Strong Commercial Bank		
Depositor		Withdraw	Don't withdraw
	Withdraw	(A, A)	(A, A)
	Don't withdraw	(0, A)	(A,0)

Customers of a failing commercial bank and customers of the bank itself are shown in Table 2. In line with the underlying strategy, the bank will have a positive response when the depositor withdraws their money and a negative response when the depositor does not. If the bank chooses to give a positive response, the depositor will withdraw their cash; however, if the bank decides to provide a negative response, the depositor will withdraw their funds a second time. As a result, the only option to reach the Nash equilibrium in this game is for depositors to withdraw funds and for weak commercial banks to respond adversely.

Table 2. Game matrix

	Weak Commercial Bank		
Depositor		Withdraw	Don't withdraw
	Withdraw	(A, B)	(A, C)
	Don't withdraw	(B, A)	(B,0)

3.2 Game Between Depositors

Basic Model: Only 2 Investors in the Bank

Let's begin with a standard two-player model, shall we? Two investors have deposited a combined amount of D with a financial institution. The bank has invested these funds in a business with a longer time horizon. If the bank is penalised by being required to sell its investment in the project before its completion, 2r may be recovered, provided that D is > r > D/2 combined. If the financial institution allows the investment to develop, the project will pay 2R, where R>D. For the sake of simplicity, let us assume that no discounting is occurring.

The payment matrix is represented as follows in table 3:

Table 3. Game matrix

	Investor 2		
Investor 1		Withdraw	Don't withdraw
	Withdraw	(r,r)	(D,2r-D)
	Don't withdraw	(2r-D,D)	(R, R)

Thus, there are two pure-strategy Nash Equilibrium:

On the one hand, both investors pull their money out, resulting in a payment to (r,r). On the other hand, neither of the investors decides to get out, which results in a payout (R, R). To put it another way, if Investor 1 learns that Investor 2 is withdrawing his deposits, Investor 1 will likewise withdraw his money. And it will result in a stampede at the bank. Further Discussion: The Proportion of Depositor Who Withdraw Their Money Early. Assume the bank has 10,000 clients who deposit $10,000 apiece in fixed-term accounts with the same maturity date. We received 10,000 deposits from people, which we split into two groups. Group A comprises fifty persons who have donated a total of $500,000, or 0.5% of all depositors. Group B comprises the remaining 99.5% of depositors, with 9,950 depositors totaling $99.5 million. The bank's available money was allocated to several operations. Other than that, these assumptions apply to the prior game [4]. If the bank withdraws the monies before the deadline, it will be fined 20% of the total amount. Groups A and B will get an additional 20% of their revenue from the bank at the time of payment. The second stage consists of playing the following game to determine if Groups A and B withdrew money ahead of schedule (in Table 4).

Table 4. Game matrix (one-tenth of a million dollars per unit)

		Group 2	
		Withdraw	Don’t withdraw
Group 1	Withdraw	(40,7960)	(50, H)
	Don’t withdraw	(0,8000)	(60,11940)

(7960<**H**<11940)

If all Group A and Group B depositors pull money out at once, the bank will have to pull money out of the investment. For this scenario, the bank will be charged a 20% penalty for prematurely withdrawing cash, and only 80 million yuan would be available for settlement. Each investor may withdraw a maximum of 8,000 yuan right now.

The bank will be compelled to get out of the project, and only 80 million yuan will be given to the majority of participants if group B withdraws early, meaning that most participants withdraw early. Still, a small number of participants don't withdraw early. Because there is insufficient cash to pay out the minority upon maturity, the bank fails. Even if just a fraction of Group A customers withdrew their money early, the bank would have enough to cover all their deposits of $500,000 and yet have enough left to generate a profit. The bank will have enough money to pay Group B when the project is complete. After considering, any penalties, the customer's final capital H must be more than 79.6 million yuan and less than the bank's maximum payment of 11.94 million yuan.

As a result, we look for the Nash equilibrium: When minority group A cashes out before the maturity date, majority group B cashes out at maturity (because H>is greater than 7960). When group A (the minority) decides to resign at maturity, group B (the majority) also decides to retire (since H is less than 11940). Therefore, Group B should priorities the "don't withdraw" approach. Given that 40 is more than 0, if group B withdraws its cash before maturity, then group A will do the same (because 60 is greater than 50). Group A is exhibiting "bandwagon" behavior because its members follow the lead of the group's majority.

This means that early withdrawals from a small number of customers will avoid widespread panic.

4. Practical Example

Before Northern Rock, the last time there was a bank run in the UK was in 1866 (in conjunction with Overend Garney). Northern Rock's run gave economists a once-in-a-lifetime opportunity to test their theoretical model in practice. The government's inability to keep its word, depositors' common concerns, and the influence of the media all played a role.

In August 2007, the US subprime loan crisis expanded to European and American real estate, credit, bond, and stock markets. The "credit crunch" caused by a lack of financial institution trust spread from the US to Europe, and Northern Rock, which depended on interbank lending for liquidity, experienced funding issues. The "subordinated debt crisis" in European banking began in September with the Northern Rock Bank run. Northern Rock suffered early in the global financial crisis, which started in August 2007 with the fall of numerous Societe Generale-sponsored hedge funds. UK bank runs began in 1866 before Northern Rock. The Northern Rock crisis allowed economists to test their theoretical bank run models. Northern Rock received most of its investment from other banks after going public in 1997. Northern Rock's financing comes from wholesale markets and retail deposits. Due to the stability of its retail deposit financing, Northern Rock relies on wholesale markets for much of its funding, making it more exposed to market fluctuations.

Comparing Northern Rock's responsibilities before and after the run helps explain the run. By 2007, the bank's liabilities were £28.5 billion after supporting Northern Rock. These dates are constant for covered bonds and securitized notes. Covered bonds grew from €8.1 billion in June to

€8.9 billion in December. Securities fell from $45.7bn to $43bn. Retail deposits and wholesale liabilities fell greatest, from £26.7 billion in June to £11.5 billion in December [5].

Northern Rock's wholesale short-term financing resembles institutional investor-targeted off-balance-sheet products [4]. Combining the discussion's important points yields the following. First, Northern Rock's liquidity issue is not caused by ordinary depositors outside banks, as dramatic as they seem on TV. Covered bonds and CDO investors are not. Short- and medium-term creditors who bought Northern Rock bonds and left the market caused the liquidity crisis. According to the coordination failure model, individual savers depart because they fear others will go, leaving no assets for those who stay. While certain coordination components contributed to the August 2007 financial crisis, the withdrawal of credit impacted the whole market, not just a segment of the institution. Thus, if there was a run owing to a lack of coordination, it came from all institutions that used short-term funding, not simply Northern Rock. By examining the make-up of liabilities before and after the bank run, we may get some insight into the reasons for the panic at Northern Rock. The following is an excerpt from Northern Rock's 2007 annual report and illustrates this. Data for the bar graph on the right was collected at the year's end, long after the run and the Bank of England's liquidity support had stabilised the market. The principal liabilities of Northern Rock as of the end of June 2007 are shown in the bar chart on the left.

Ultimately, the bank's liabilities in 2007 reached £28.5 billion after the liquidity support provided to Northern Rock. This is the most noticeable distinction. Covered and securitized corporate bonds, however, are quite stable on these dates. The value of covered bonds rose in June to 8.1 billion euros from 8.9 billion euros in December. Overall securitization activity decreased from $45.7 billion to $43 billion. The biggest reduction was in consumer deposits and wholesale debt, which fell from $26.7 billion in June to $11.5 billion in December. That's a drastic drop. Northern Rock's wholesale short-term financing is quite comparable to what's provided by SIVs and pipelines, two offshore sources of institutional funding. It's easy to draw parallels between the two since they share many characteristics. Short-term (less than a year) funding is especially susceptible to the capital market liquidity crisis that began in August 2007. Despite this, there was a significant wholesale outflow in the year's second half due to the lack of new loans and aging deposits. The previous year had net outflows of $11.7 billion [6].

The following may be inferred by combining the most crucial elements of the preceding discussion with the data provided in the statements. The liquidity crisis was initially caused by something other than the well-publicized retail depositors outside Northern Rock's facilities. Additionally, covered bond and other securitized security investors lost out. Models of cooperation failure established by Bryant, Diamond, and Dybvig postulate that a run occurs when each depositor fears that the others will withdraw their funds [7,8]. It is the property of no one at all. Many other elements contributed to the financial crisis that started in August 2007; nonetheless, it is important to remember that credit loss hurt many institutions and the market. The Northern Lock is accountable, along with all the other institutions that rely on this kind of short-term liquidity when a run arises because of a lack of coordination [9,10].

5. Conclusion

A "bank run" occurs when many depositors suddenly withdraw their funds from the same bank due to widespread panic about the institution's viability. In a bank run, the institution's liquidity is at greatest risk. One of the most time-honored measures of an organization's exposure to financial liquidity risk is the current ratio. A line of credit is an example of a conventional mitigator. In addition, we examined two case studies of bank runs. The depositor and the bank participate in the first game, while both sets of players play the second game. Depositors in the coordinated failure model of bank runs are seen as rational actors who base their choices to join the run on their observations of the behaviors of other depositors. Nothing else can limit their actions in any manner. Northern Rock has many debtors, but many are seasoned investors who will adjust their level of risk-taking as events unfold. This suggests that these investors are willing to lend money and actively seek borrowers when the perceived degree of risk is low since their balance sheets may be expanded. No capital risk limitations will be in place if the assessed risk is minimal. However, in times of crisis, risk limitations kick in, prompting banks to limit their exposure. The practical action is to decrease risk exposure while market volatility is present. However, the progressive reduction in Northern Rock's exposure to creditors is run from the bank's point of view. It is crucial to remember the limitations under which creditors operate while making decisions. The game concerning the depositor and the bank leads to a different Nash equilibrium depending on whether the bank is strong or weak. Further, the rivalry between the two groups suggests that a handful of early withdrawals will not lead to a bank heist. Our group used the 2007 bank robbery at Northern Rock as a real-world example of a bank run. See this as an illustration of the potential utility of our game theoretic model.

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