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銀行擠兌、暫停存款提領與銀行業之市場監督機制

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銀行擠兌、暫停存款提領與銀行業之市場監督機制

Bank Runs, Convertibility Suspension, and Market Discipline in the Banking Industry

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中英文摘要

中文摘要

本計畫探討銀行擠兌的本質及相關政策議題。本計畫由兩篇論文所組成。在第一篇論文中，我們發現存款人提款的誘因會受到銀行相關資訊的品質及數量的影響。當存款人預期包含許多雜訊之資訊將被揭露、或預期很精確的資訊將不會被揭露，銀行擠兌都會發生。這樣的擠兌並不效率。該文也探討如何用暫停存款提領的方式來提高銀行擠兌的效率。暫停存款提領的措施有兩個好處。一是迫使存款人延後其提領決策，讓存款人有更多銀行相關資訊時再決定是否提領。二則是在暫停提領期間，政府或負責銀行票據交換之機構常會查核銀行的狀況並予以揭露，使存款人在銀行再度開始營業時有更精確的資訊來決定是否提領。透過這些機制，暫停存款提領可以提高銀行擠兌的效率。若其所造成之存款人流動損失不大，則暫停存款提領將可提高存款人福利。

本計畫的第二篇論文討論銀行資訊透明程度與傳染性擠兌間之關係。在該文中，傳染性擠兌是指因其他銀行（非擠兌發生銀行）之負面消息所引發的不效率擠兌。文中發現，當銀行揭露更多資訊時，傳染性擠兌發生的機率可能變高或變低。又當政府要求銀行揭露更多資訊時，資訊品質較差的銀行較易發生傳染性擠兌。此外，銀行業體質不佳時傳染性擠兌亦較容易發生。第二篇論文也討論了如何以銀行自有資本比率管制或存款保險來解決傳染性擠兌的問題。文中證明，如果銀行持有足夠的自有資本、或政府提供適當的存款保險，則銀行揭露更多訊息必定會降低傳染性擠兌的發生機率並提高存款人福利。此結果的政策含意為：當政府要求銀行揭露更多資訊時，應注意銀行自有資本比率管制或存款保險等配套措施以使存款人能更有效率的運用資訊。

關鍵詞：銀行擠兌、傳染性恐慌、銀行自有資本比率管制、暫停存款提領、存款保險、資訊透明度

Abstract

This project studies the nature of information-based bank runs and the related policy issues. It is composed of two related paper. The first one shows that the depositors' incentives to withdraw are affected by their expectations on both the amount and the quality of the bank-related information that will be revealed in the future. More specifically, a bank run will occur when depositors learn that more noisy information will arrive, or when they realize that precise information about bank returns will not be revealed. Such bank runs are inefficient. The paper also demonstrates how convertibility suspension can improve the efficiency of bank runs. By forcing depositors to delay their withdrawing decisions until more information is revealed, and by producing more precise information about bank assets, convertibility suspension makes bank runs a more efficient mechanism for monitoring banks. It is shown that convertibility suspension is beneficial if the fraction of depositors who have liquidity needs during the suspension period is small, or if the liquidity losses of the depositors who cannot successfully withdraw are not serious.

The second paper investigates the relationship between information transparency and the fragility of the banking industry. It is found that an improvement in information transparency may either increase or decrease the chance of a contagious run. It predicts that, when a government imposes stricter information disclosure rules in the banking industry, contagious runs are more likely to occur to banks with poor information quality. In addition, contagious runs are more likely to happen when the banking industry is weak.

The second paper also demonstrates that the contagious run problem can be solved if banks hold enough capital or if some of the deposits are insured. It is shown that, once contagious runs are eliminated, an improvement in information transparency always improves depositor welfare. This result implies that, when a government requires banks to disclose more precise information, it should also adopt mechanisms that can induce depositors to use information efficiently.

***Keywords*:** bank run, contagion, bank capital regulation, convertibility suspension, deposit insurance, information transparency

計畫內容

Part 1. Information-based Bank Runs and Convertibility Suspension

1. Introduction

This paper studies how convertibility suspension improves the efficiency of information-based bank runs. Even though most bank runs are triggered by adverse information about bank assets, they are usually viewed as panics rather than an effective mechanism for monitoring banks. This implies that somehow the processes of bank runs may incur inefficiencies. In the banking literature, several papers demonstrate why runs can be inefficient. Diamond and Dybvig (1983) show that the sequential service constraint imposed in the deposit contract creates a negative payoff externality among depositors. This externality results in multiple equilibria, and a bank run is the Pareto dominated equilibrium. Chari and Jaganathan (1988) suggest that inefficient bank runs occur when depositors misinterpret liquidity shocks as informational shocks. Extending Diamond and Dybvig (1983), Chen (1999) illustrates that payoff externalities induce depositors to have too much incentive to withdraw. As a result, depositors may jump on early noisy information about bank returns and start a bank run even if they know that more precise information will arrive in the near future.

This paper contributes to this literature by proposing that, even if depositors choose the Pareto dominant equilibrium when there are multiple equilibria, a bank run can still occur *before* any adverse information about bank assets is revealed. Such a run is obviously inefficient. The paper shows that the depositors' incentives to withdraw are affected by their expectations on both the amount and the quality of the bank-related information that will be revealed in the future. More specifically, a bank run will occur when depositors learn that more noisy information will arrive. It can also happen when depositors realize that precise information about bank returns will not be revealed.[1]

The intuition for these results is as follows. As shown in Chen (1999), depositors have too much incentive to withdraw. Therefore, an information-based bank run may

[1] The terms "noisy information" and "precise information" will be rigorously defined in Proposition 2

reduce the depositors' expected payoff. When the information about bank returns is noisy, a bank run based on this information is likely to be inefficient, so the depositors' payoff for waiting until the information arrives will be lower than what they get from withdrawing before the information is revealed. Knowing this, depositors will start a run when they learn that noisy information will arrive. On the other hand, when the information about bank returns is precise, an information-based bank run occurs only when the bank should be liquidated. Hence, depositors are willing to make their decisions after the information is revealed. Once they learn that the precise information will not be revealed, they will no longer wait and will start a bank run.

This paper has policy implications. It suggests that convertibility suspension can improve the efficiency of bank runs in at least two ways. First, convertibility suspension forces depositors to delay their withdrawing decisions until more precise information is revealed. Second, the government or bank clearing houses may examine banks' financial conditions during the suspension periods and reveal the new information to depositors when banks reopen. This not only allows depositors to base their withdrawing decisions on more precise information, but also reduces the depositors' incentives to withdraw *before* convertibility is suspended. It will be shown that convertibility suspension can be justified if the proportion of depositors who have liquidity during the suspension period is not large, or if the liquidity losses of the depositors who cannot successfully withdraw are not serious.

This paper has new results not documented in the literature. Unlike Diamond and Dybvig (1983), bank runs are inefficient in this paper not because they are the Pareto-dominated equilibria, but because the deposit contract induces depositors to use their information inefficiently. Chari and Jaganathan (1988) also study the welfare effects of convertibility suspension. However, because their model is basically a one-period model, it cannot demonstrate the important point that convertibility suspension forces depositors to use the information more efficiently. The model in this paper is much simpler than that in Chen (1999). The simplicity of the model allows this paper to show much more results without losing tractability. Moreover, Chen (1999) does not study the welfare effects of convertibility suspension, which is the main focus of this paper.

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in Section 3.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 is the analysis of the model. Section 4 discusses the welfare effects of convertibility suspension. Concluding remarks are in Section 5

2. The Model

This is a four-date (dates 0, 1A, 1B, and 2) model.[2] There are a bank and numerous atomistic depositors in the model. At date 0, each depositor receives an endowment of $1. A depositor can either deposit her endowment at the bank, or invest the endowment in a long-term paper that matures at date 2. The paper is divisible. For each dollar invested, the paper yields R with probability p and yields nothing with probability $1 - p$, where p is a random variable and $p = p_0$ at date 0. It is assumed that $p_0 R > 1$, so the paper's expected rate of return is positive. The paper can be liquidated at date 1A or 1B. For each dollar invested at date 0, liquidation yields $1 at date 1A or 1B. The returns of all the depositors' long-term papers are perfectly correlated.

All depositors die at date 2, and they may have liquidity needs. There are three types of depositor; type-1A and type-1B depositors have liquidity needs, while type-2 depositors do not. For j = A or B, a type-1j depositor will suffer a liquidity loss X if she consumes less than r by the end of date 1j. At date 0, depositors do not know their types. Liquidity shocks are revealed sequentially. Type-1A depositors learn their type at date 1A; type-1B and type-2 depositors learn their types at date 1B. Depositors are identical at date 0, that is, the probability that each depositor will become a certain type of depositor is the same. Also, at date 1A, after type-1A depositors learn their type, the probability that each non-type-1A depositor will become a type-1B depositor is the same. Let U_i denote the utility function of a type-i depositor, and c_j denote a depositor's consumption at date j. The depositors' utility functions can be written as follows.

$$U_{1A}(c_{1A}, c_{1B}, c_2) = \begin{cases} c_{1A} + c_{1B} + c_2 - X & \text{if } c_{1A} < r, \\ c_{1A} + c_{1B} + c_2 & \text{if } c_{1A} \geq r. \end{cases}$$

$$U_{1B}(c_{1A}, c_{1B}, c_2) = \begin{cases} c_{1A} + c_{1B} + c_2 - X & \text{if } c_{1A} + c_{1B} < r, \\ c_{1A} + c_{1B} + c_2 & \text{if } c_{1A} + c_{1B} \geq r. \end{cases}$$

$$U_2(c_{1A}, c_{1B}, c_2) = c_{1A} + c_{1B} + c_2.$$

At date 0, it is known that the proportions of type-1A, type-1B, and type-2 depositors

[2] It is assumed that date 1A precedes date 1B.

are t_A, t_B, and $1 - t_A - t_B$, respectively.

At date 1B, depositors may receive a public signal s about p. At date 0, it is known that s will be revealed with probability α and will not be revealed with probability $1 - \alpha$, where α is a constant between 0 and 1. The signal s is equal to either H or L. If the return of the long-term papers will be R, then $s = H$ with probability q and $s = L$ with probability $1 - q$, where $0.5 \leq q \leq 1$. If the return of the long-term papers will be 0, then $s = H$ with probability $1 - q$ and $s = L$ with probability q. Let p_H and p_L denote the probabilities that the long-term papers' return is R given $s = H$ and $s = L$, respectively. It can be shown that

$$p_L(p_0, q) \equiv \frac{p_0(1-q)}{p_0(1-q)+(1-p_0)q} \leq p_0 \leq p_H(p_0, q) \equiv \frac{p_0 q}{p_0 q+(1-p_0)(1-q)}. \tag{1}$$

q can be explained as the precision of the signal. The larger the q, the more precise the signal is in the sense that both $p_0 - p_L(p_0, q)$ and $p_H(p_0, q) - p_0$ become larger.

At date 1A, depositors learn whether s will arrive at date 1B. At both dates 1A and 1B, the information about liquidity shocks and the information about the signal are revealed the same time. That is, type-1A depositors learn their types and all the depositors learn whether s will be revealed simultaneously at date 1A. In case s will be revealed, the non-type-1A depositors learn their types and all the depositors learn the value of s simultaneously at date 1B.

Under the above setting, when a depositor makes the investment herself, she has to suffer the liquidity loss X if she becomes a type-1A or type-1B depositor. The existence of a bank may improve depositor welfare. At date 0, the bank collects deposits from depositors, and invests the proceeds in a long-term paper. The bank's paper is identical to those of depositors. At date 0, the bank offers a deposit contract (d_{1A}, d_{1B}, d_2) to depositors. For each dollar deposited at date 0, the bank promises to pay d_j dollars if the depositor withdraws at date j, where j = 1A, 1B, or 2. Without loss of generality, assume that at each date depositors decide whether to withdraw *after* the information is revealed.

When depositors withdraw, the bank cannot distinguish among different types of depositor, so depositors are served according to the time they arrive at the bank. That is, the first-come, first-served rule is imposed. For now, assume that convertibility suspension is not allowed: the bank has to keep open at date 1 unless it runs out of money. The feasibility of using convertibility suspension to improve the efficiency of bank runs will be discussed in Section 4. Also, it is assumed that there is no deposit insurance. The banking industry is competitive, so the bank's expected profit is zero. Finally, assume that the parameter values satisfy

$$t < \min\left\{\frac{R-r}{rR-r}, \frac{1}{r+(1-1/r)X}\right\}, \tag{2}$$

where $t \equiv t_A + t_B$. The reasons for requiring (2) will become clear in the next section.

3 The Analysis of the Model

This section studies the conditions under which a bank run will occur. To simplify the exposition, we consider only the cases where depositors make deposits at date 0. We will assume that the bank will set $d_{1A} = d_{1B} = r$ and $d_2 = d_2^*$, where

$$d_2^* \equiv \frac{(1-tr)}{1-t}R. \tag{3}$$

The result $d_{1A} = d_{1B} = r > 1$ is important. Although we do not rigorously prove it, it can be argued that among all the contracts that may avoid the depositors' liquidity losses, the deposit contract stated above is the one that maximizes depositor welfare.[3] Given this contract, if all depositors withdraw before the bank's long-term investment matures, those who arrive at the bank after it runs out of money will receive nothing. This creates negative a payoff externality among depositors: the withdrawal of a depositor will reduce the payoff of depositors who have not yet withdrawn. As a result, depositors have too much incentive to withdraw. Also note that by (2), $t < (R-r)/(rR-r)$, which implies d_2^* is strictly larger than r. If d_{1A} or d_{1B} is greater than d_2, all depositors would withdraw at date 1A.

The game is solved backwards. For simplicity, we study only the symmetric pure-strategy subgame-perfect Nash equilibria. Also, we assume that depositors choose the Pareto dominant equilibrium when there are multiple equilibria.[4] As to the definition of a bank run, we will say that a bank run happens at a certain date if all the

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[3] The deposit contract offered by the bank can be justified as follows. To avoid the liquidity costs of type-1A and type-1B depositors, the contract must satisfy $d_{1A} \geq r$ and $d_{1B} \geq r$. Setting d_{1A} or d_{1B} greater than r is not optimal for two reasons. First, the expected return of the long-term paper is positive. The smaller the d_{1A} and d_{1B} are, the more resources can be invested until the long-term paper matures. Second, as will be seen, given $d_{1A} = d_{1B} = r > 1$, depositors have too much incentive to withdraw at date 1. An increase in d_{1A} or d_{1B} will worsen this problem. Therefore, the bank should set $d_{1A} = d_{1B} = r$. The zero-profit condition for the bank implies that $d_2^* = (1-tr)R/(1-t)$.

[4] The purpose of making this assumption is to demonstrate the point that information-based bank runs are still inefficient even if depositors choose the Pareto dominating equilibrium.

depositors who have not withdrawn yet withdraw. As in Diamond and Dybvig (1983) and Chen (1999), it can be shown that (i) a bank run is always an equilibrium in all the subgames, and (ii) a bank run is the Pareto dominated equilibrium when there are multiple equilibria.[5] Therefore, in our model a bank run occurs if and only if it is the only subgame-perfect Nash equilibrium.

Let us start from the subgame of date 1B. Suppose that only type-1A depositors withdraw at date 1A. At date 1B, type-1B depositors always withdraw to avoid the liquidity loss. The remaining depositors may either withdraw or wait until date 2. Their incentives to withdraw depend on their belief on the others' strategies. Consider the withdrawing decision of a non-type-1B depositor. Given p,[6] if she believes that only type-1B depositors will withdraw at date 1B, her payoffs for withdrawing and for not withdrawing are r and pd_2^*, respectively. Therefore, at date 1B, "only type-1B depositors withdraw" can be sustained as an equilibrium if and only if $pd_2^* \geq r$, or

$$p \geq p_N \equiv \frac{(1-t)r}{(1-tr)R}. \tag{4}$$

In other words, a bank run will occur if and only if $p < p_N$. When a bank run occurs at date 1B, the expected payoff for a non-type-1A depositor is

$$V_{BR} \equiv \frac{1-t_A r}{(1-t_A)} - \frac{t_B(r-1)}{(1-t_A)^2 r} X, \qquad \ldots (5)$$

where the first term in the right hand side is the amount of money a non-type-1A depositor expects to receive from the bank, and the second term is the expected liquidity loss of a non-type-1A depositor.[7] It can be easily shown that V_{BR} is smaller than r, which is an intuitive result because the depositors who can successfully withdraw during a bank run should enjoy a higher payoff. On the other hand, when a bank run does not occur at date 1B (so only type-1B depositors withdraw at date 1B),

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[5] If 'no depositor withdraws' can be sustained as a Nash equilibrium in a date 1 subgame, the depositors' equilibrium payoff must be no smaller than r. In the bank run equilibrium, the depositors' payoff is V_{BR} in equation (6), which is strictly less than 1.

[6] Depending on whether s is revealed, the value of p may be p_0, $p_H(p_0, q)$, or $p_L(p_0, q)$.

[7] Note that type-1A depositors have already withdrawn at date 1A. Let N denote the total number of depositors. At date 1B, the amount of money left in the bank is $(1 - t_A r) N$ and the total claim of non-type-1A depositors is $(1 - t_A) r N$ if all of them try to withdraw at date 1B. Therefore, the probability that a non-type-A depositor can successfully withdraw is $(1 - t_A r)/ [(1 - t_A) r]$. The expected amount that each non-type-1A depositor can withdraw equals the probability she can successfully withdraw multiplied by r. The expected liquidity loss of a non-type-1A depositor equals the probability that she will become a type-1B depositor ($t_A/(1 - t_A)$) multiplied by the probability that she cannot successfully withdraw multiplied by X.

the expected payoff for a non-type-1A depositor is[8]

$$V_{NW}(p) \equiv \frac{t_B}{1-t_A} r + \frac{1-t_A-t_B}{1-t_A} p\, d_2^* \ . \qquad \text{... (6)}$$

Equations (5) and (6) together imply that depositors have too much incentive to withdraw at date 1B. To see this, note that if non-type-1A depositors could coordinate their actions to maximize their joint welfare,[9] they would prefer a bank run to occur at date 1B when $V_{NW}(p_0) < V_{BR}$, or equivalently

$$p_0 < p^* \equiv \frac{1}{R}[1 - \frac{t_B(r-1)X}{(1-t_A)r(1-tr)}] \, . \qquad \text{… (7)}$$

Comparing (4) and (7), it can be easily seen that $p^* < p_N$. So an inefficient bank run will occur if $p^* < p_0 < p_N$.

Now back to date 1A. After the liquidity shocks are revealed, all the type-1A depositors will withdraw. The non-type-1A depositors' incentives to withdraw depend on whether the signal *s* will be revealed at date 1B. In case *s* will not be revealed, a bank run will occur at date 1A if and only if $p_0 < p_N$. Alternatively, if depositors learn that *s* will be revealed, whether a bank run will occur depends on the parameter values. When $p_L(p_0, q) \geq p_N$, a bank run will never occur at date 1B. Knowing this, only typa-1A depositors will withdraw at date 1A. On the other hand, when $p_H(p_0, q) < p_N$, a bank run would always occur at date 1B if it did not occur at date 1A. Expecting that a bank run will occur anyway, all the depositors (both type-1A and non-type-1A) will withdraw at date 1A. Finally, when $p_L(p_0, q) < p_N \leq p_H(p_0, q)$ and no depositor withdraws at date 1A, a bank run would occur at date 1B if and only if $s = L$. The expected payoff for a non-type-1A depositor to wait until date 1B becomes

$$V_M(p_0,q) \equiv \pi_H(p_0,q)\, V_{NW}(p_H(p_0,q)) + (1-\pi_H(p_0,q))V_{BR} \, , \qquad (8)$$

where $\pi_H(p_0, q) \equiv p_0\, q + (1 - p_0)\,(1 - q)$ is the prior probabilities of $s = H$. In this case, a bank run will occur at date 1A if and only if $V_M(p_0, q) < r$. The above results can be summarized in the following proposition. The proofs of all the propositions are available from the author upon request.

Proposition 1.

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[8] With probability $t_B/(1 - t_A)$, a non-type-1A depositor becomes a type-1B depositor and withdraws at date 1B; , with probability $1 - t_B/(1 - t_A)$ she becomes a type-2 depositor and waits until date 2. Her payoff is r in the former case and is $p\, d_2^*$ in the latter one.

[9] It is assumed that non-type-1A depositors make this coordinated choice before the liquidity shocks of

(a) At date 1A, if depositors learn that s will not be revealed, the equilibrium payoff for a non-type-1A depositor is

$$W_N(p_0) \equiv \begin{cases} V_{NW}(p_0) & \text{if } p_0 \geq p_N, \\ V_{BR} & \text{if } p_0 < p_N. \end{cases} \quad (9)$$

(b) At date 1A, if depositors learn that s will be revealed, there exist a $p_{S1}(q)$ and a $p_{S2}(q)$ with $0 < p_{S1}(q) \leq p_{S2}(q) < 1$ such that the equilibrium payoff fro a non-type-1A depositor is

$$W_S(p_0, q) \equiv \begin{cases} V_{NW}(p_0) & \text{if } p_0 \geq p_{S2}(q), \\ V_M(p_0, q) & \text{if } p_{S1}(q) \leq p_0 < p_{S2}(q), \\ V_{BR} & \text{if } p_0 < p_{S1}(q). \end{cases} \quad (10)$$

(c) When depositors learn that s will not be revealed, a bank run occurs at date 1A if and only if $p_0 < p_N$. When depositors learn that s will be revealed, a bank run occurs at date 1A if and only if $p_0 < p_{S1}(q)$.

Proposition 1 says that a bank run may occur at date 1A if p_0 is not large enough. Even though the information about p has not been revealed at date 1A, depositors may withdraw if their payoff for waiting one more date is less than r. The next proposition shows how the quality of the information affects the depositors' incentives to withdraw.

Proposition 2.

(a) There is a $q_C \in (0.5, 1)$ such that $p_{S1}(q) > p_N$ if $q < q_C$, and $p_{S1}(q) < p_N$ if $q > q_C$.

(b) If $q < q_C$ and $p_N < p_0 < p_{S1}(q)$, a bank run will occur at date 1A when depositors learn that s will be revealed at date 1B.

(c) If $q > q_C$ and $p_{S1}(q) < p_0 < p_N$, a bank run will occur at date 1A when depositors learn that s will not be revealed at date 1B.

Part (a) of Proposition 2 implies that, learning that s will be revealed makes non-type-1A depositors more eager to withdraw if s is noisy, and makes them more patient if s is precise. Using part (a), parts (b) and (c) of the proposition identify the conditions under which a bank run will occur at date 1A. The intuition of part (a) of Proposition 2 can be explained as follows. When s will be revealed, non-type-1A

date 1B are realized.

depositors will use s to determine whether to withdraw. Because of the negative payoff externalities imposed in the deposit contract, a bank run may be inefficient. If s is noisy, a bank run based on s is likely to be inefficient. Knowing this, non-type-1A depositors will become more eager to withdraw at date 1A. On the other hand, if s is precise, a bank run is an effective mechanism for liquidating banks with poor asset returns. In this case, non-type-1A depositors become more patient at date 1A.

The above analysis seems to imply that depositors are always better off when the public signal becomes more precise. However, this conjecture is incorrect. The following proposition shows that, in case s is always revealed, an increase in q may either increase or decrease depositor welfare.

Proposition 3. $W_S(p_0, q)$ is not monotonically increasing in q. For any $p_0 > p_N$, there exist q_1, q_2, and q_3 with $0.5 < q_1 < q_2 < q_3 < 1$ such that

$$W_S(p_0, q_2) < W_S(p_0, q_1)=V_{NW}(p_0) < W_S(p_0, q_3).$$

Proposition 3 can be explained as follows. By (1), $p_L(p_0, 0.5) = p_0$, $p_L(p_0, 1) = 0$, and $p_L(p_0, q)$ is decreasing in q. Suppose that $p_0 > p_N$. When q is small (in the sense that p_L is still larger than p_N), non-type-1A depositors never respond to the public signal, so their equilibrium payoff is $V_{NW}(p_0)$. As q becomes larger and satisfies $p^* < p_L < p_N$, an inefficient bank run will occur when $s = L$. The non-type-1A depositors' equilibrium payoff will become smaller than $V_{NW}(p_0)$. If q is so large that $p_L < p^*$, a bank run based on $s = L$ is efficient. The non-type-1A depositors' equilibrium payoff will become larger than $V_{NW}(p_0)$.

4. Convertibility Suspension

In the previous section, we demonstrate that bank runs may be inefficient in the sense that they occur before the information about bank assets is revealed. In this section, we will show that this problem can be alleviated by convertibility suspension. Suppose that, to improve the efficiency of bank runs, the bank is allowed to suspend convertibility at date 1A when the proportion of withdrawing depositors reaches f, where f is a constant and $f \geq t_A$.[10] The bank has to reopen at date 1B, and it is not allowed to suspend convertibility again at date 1B. For simplicity, we assume that

[10] In this model, f is endogenous, and we will find the optimal f that maximizes depositor welfare.

convertibility suspension does not change the quality of the information about the bank. Later in this section we will discuss what will happen when this assumption is relaxed.

To demonstrate the value of convertibility suspension, in the rest of this section we assume that the condition stated in part (b) of Proposition 2 holds, that is, $p_N < p_0 < p_{S1}(q)$. Given this condition, a bank run will occur at date 1A when depositors learn that the signal s will be revealed at date 1B. In this case, if $f < 1/r$, the bank will stop serving depositors once the proportion of withdrawing depositors reaches f.

Note that convertibility suspension changes the total fraction of depositors who withdraw before date 2. Because the bank cannot distinguish between type-1A and non-type-1A depositors, during a date-1A bank run the fraction of successfully withdrawing depositors is f for both groups. This implies that the proportion of depositors suffering liquidity losses at date 1A is $(1 - f)\, t_A$. These type-1A depositors will behave like type-2 depositors at date 1B because they no longer have liquidity needs. For the non-type-1A depositors who successfully withdraw at date 1A, some of them become type-1B depositors at date 1B. These type-1B depositors will do nothing at date 1B because they have already withdrawn at date 1A.[11] From the above description, if convertibility is suspended at date 1A and a bank run does not occur at date 1B, the fraction of depositors who withdraw before date 2 is

$$t_C(f) \equiv f + (1 - f)\, t_B. \qquad \ldots (11)$$

In this case, the largest amount of money that a depositor who withdraws at date 2 can receive becomes

$$d_{2C}(f) \equiv \frac{1 - t_C(f) r}{1 - t_C(f)} R\,. \qquad \ldots (12)$$

Since the deposit contract is designed to maximize depositor welfare, we assume that the deposit contract (d_{1A}, d_{1B}, d_2) is automatically adjusted and becomes $(r, r, d_{2C}(f))$ once convertibility suspension is triggered.

To reduce the probability of an inefficient bank run by convertibility suspension, it must be the case that a bank run will not occur at date 1B when $s = H$.[12] To satisfy this condition, we require

$$p_H(p_0, q) \geq r / d_{2C}(f),$$

[11] The proportion of these type-1B depositors is $f\, t_B$.

[12] If a bank run occurs when $s = H$, then it must also occur when $s = L$. In this case, the only function of convertibility suspension is to delay the timing of a bank run rather than to reduce the probability of

or equivalently,[13]

$$f \le \bar{f} \equiv \frac{\dfrac{p_H R - r}{r(p_H R - 1)} - t_B}{1 - t_B} . \qquad \ldots (13)$$

Equation (13) imposes an upper limit on f. If (13) does not hold, d_{2C} will become too low to prevent non-type-1B depositors from withdrawing at date 1B even if $s = H$, which means a bank run will always occur at date 1B. Hence, if (13) is violated, convertibility suspension will not have the function of reducing the probability of an inefficient bank run.[14] In addition to requiring $f \le \bar{f}$, to simplify the exposition we assume that the parameter values satisfy[15]

$$p_L(p_0, q) < r / d_{2C}(t_A),$$

so a bank run will occur at date 1B when $s = L$. Given the above setting, the following proposition states the depositor welfare when s will be revealed.

Proposition 4. Suppose that (i) $p_N < p_0 < p_{S1}(q)$, (ii) $p_L(p_0, q) < r / d_{2C}(t_A)$, and (iii) at date 1A depositors learn that s will be revealed.

(a) When convertibility suspension is allowed, depositor welfare is

$$W_{CS}(f) \equiv 1 + \pi_H [1 - t_C(f) r](p_H R - 1) - (1 - f) t_A X - (1 - \pi_H)(1 - \frac{1}{r}) t_B X . \qquad \ldots (14)$$

(b) The optimal f is t_A if and only if

$$t_A \le t_A^* \equiv \frac{\pi_H (1 - t_B) r (p_H R - 1)}{X} . \qquad \ldots (15)$$

If (15) is violated, the optimal f is $\bar{f}$.

(c) When $t_A \le t_A^*$, convertibility suspension improves depositor welfare if and only if

$$\pi_H [1 - (t_A + t_B - t_A t_B) r](p_H R - 1) > X[(\frac{1}{r} - t_A) t_A - \pi_H (1 - \frac{1}{r}) t_B]. \qquad \ldots (16)$$

Proposition 4 can be explained as follows. Part (a) of the proposition states the

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an efficient bank run.

[13] Suppose that depositors believe that only type-1B depositors who have not withdrawn yet will withdraw at date 1B. Given $s = H$, the payoff for a non-type-1B depositor who has not withdrawn yet is $p_H d_{2C}$ if she waits until date 2 and is r if she withdraws at date 1B. Therefore, a bank run will occur at date 1B if and only if $p_H(p_0, q) < r / d_{2C}$.

[14] The assumption $p_0 > p_N$ implies $p_H > p_0$, which implies non-type-1B depositors are better off if a bank run does not occur at date 1 B when $s = H$.

[15] Note that $f \ge t_A$ and d_{2C} is decreasing in f by (13). Therefore, a bank run will always occurs when $s =$

depositor welfare when the signal s will be revealed and convertibility suspension is allowed. In the right hand side of (14), the sum of the first two terms is the amount of money a depositor expects to receive from the bank,[16] and the sum of the last two terms is the expected liquidity losses.[17] Part (b) of the proposition proposes that the bank should set f as small as possible when t_A is not large. This result is intuitive. If only few depositors have liquidity needs at date 1A, it is better to minimize the amount of money withdrawn from the bank so that more resources can be left for the long-term investment.

Part (c) of the proposition states the condition under which convertibility suspension improves depositor welfare when t_A is not high. Note that (16) holds when t_A or X is small.[18] That is, convertibility suspension improves depositor welfare if the fraction of type-1A depositors or the liquidity loss is small. One implication of this result is that convertibility suspension is likely to be beneficial if the suspension period is short. When the suspension period is short, the number of depositors who have to suffer liquidity losses should be small, so convertibility suspension is likely to improve depositor welfare. Also, if depositors can trade their bank claims for cash with a small discount during the suspension period (as mentioned in Calomiris (1990)), then X is not large. In this case, convertibility suspension should improve depositor welfare.

Before ending this section, we briefly discuss the information production function of convertibility suspension. As mentioned above, for simplicity we assume that convertibility suspension does not change q. This assumption is not realistic. In the U.S. history, bank clearing houses often verified banks' financial conditions during the suspension periods, and allowed only sound banks to reopen. In other words, convertibility suspension may result in more precise information about bank assets. To reflect this idea, suppose that during the suspension period the government will

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L if $p_L(p_0, q) < r/d_{2C}(t_A)$.

[16] If there were no convertibility suspension, all the money at the bank is withdrawn at date 1A. Convertibility suspension reduces the probability of a bank run by π_H. When the run does not happen, part of the bank's deposits (fraction $1 - t_c r$) is invested in the long-run paper and will return R for each dollar's investment with probability p_H. Therefore, the second term of the right hand side of (14) is the expected investment gain created by convertibility suspension.

[17] When convertibility is suspended, part of the type-1A depositors (fraction $(1 - f)\, t_A$) suffer liquidity losses at date 1A. In addition, if $s = L$ so that a bank run reoccurs at date 1B, type-1B depositors who cannot successfully withdraw have to suffer liquidity losses. The last two terms in the right hand side of (14) reflect these two effects, respectively.

[18] When t_A approaches 0, (16) holds because its right hand side is negative and its left hand side is positive.

examine the bank and reveal the examination results to depositors when the bank reopens. As a result, the information quality becomes $q_1 > q$. In addition, assume that

$$p_{S1}(q_1) < p_0 < p_{S2}(q_1). \qquad \dots (17)$$

From the results in Section 3, (17) implies two things. First, when the bank reopens, a bank run will occur at date 1B if and only if $s = L$. Second, if non-type-1A depositors expect that the information quality will become q_1, "only type-1A depositors withdraw" can be sustained as a Nash equilibrium of the date-1 subgame.[19] From these results, obviously the bank should set $f = t_A$ and always "suspend the convertibility" when s will be revealed. However, since no non-type-1A depositor withdraws at date 1A, a bank run does not really happen in this case, and convertibility suspension does not cause any liquidity losses. Although this result looks straightforward, it demonstrates an important point: by improving the quality of the information about banks, convertibility suspension can induce depositors to be more patient, thus reducing the welfare losses of inefficient bank runs.

Finally, in addition to the above channels, there is another way convertibility suspension can also improve depositor welfare. If depositors are allowed to choose a Pareto dominated equilibrium so that a panic run defined in Diamond and Dybvig (1983) happens, convertibility suspension can force depositors to delay their withdrawing decisions. This may lead to an equilibrium with higher depositor welfare.

5. Concluding Remarks

This paper shows that a bank run can occur even before the information about bank assets is revealed. It also demonstrates that convertibility suspension can reduce the probability that an inefficient bank run will happen. The model in this paper can be extended to study various policy issues. For example, it can be used to investigate the welfare effects of bank information disclosure regulations. When a government requires banks to reveal more information, depositors can use more information to decide whether to withdraw. However, as shown in Proposition 3, such a change may decrease rather than increase depositor welfare. It is interesting to see whether requiring banks to reveal more information is always welfare-improving.

The model in this paper can also be extended to study other policy issues related

[19] The fact that $p_{S1}(q_1) < p_0$ implies that $V_M(p_0, q_1) > r$. Therefore, "only type-1A depositors withdraw" can be sustained as a Nash equilibrium of the date-1 subgame

to bank runs. For example, since the depositors' withdrawing decisions can be affected by deposit insurance and the bank's capital ratio, extending this model to design the optimal deposit insurance system and bank capital regulations will be a promising topic for future study.

Part 2. Contagious Bank Runs and Information Transparency in the Banking Industry

1. Introduction

This paper investigates the relationship between information transparency in the banking industry and contagious runs. Imposing market discipline to alleviate banks' moral hazard problems has become an important part of bank regulation policies around the world. To enforce market discipline, regulators have to adopt a strict bank disclosure rule so that market participants have enough information to discipline banks. However, some people worry that more information disclosure may result in a fragile banking industry. As depositors learn more information about their banks, there may be a higher chance that they will respond to adverse information about banks and start bank runs. If this is the case, an improvement in information transparency in the banking industry may reduce rather than increase social welfare.

This paper studies whether more information disclosure will increase the chance of a contagious bank run. In this paper, the optimal deposit contract has to satisfy depositors' liquidity needs, so the amount that an early withdrawing depositor gets is larger than the liquidation value of her original deposits. This result and the sequential service constraint imposed in the deposit contract together create negative payoff externalities among depositors, thus inducing depositors to have excessive incentive to withdraw when they learn adverse information about their banks. We show that a contagious run can occur under this setting. That is, news about a bank may trigger a bank run on another bank. A contagious run is inefficient in our model because depositors' withdrawing decisions can be based on more precise information if they wait until information about their own bank is revealed.

In our model, improving banks' information transparency may either increase or decrease the chance that a contagious run will occur. To see this, consider depositors of a bank (we will call it bank B). An improvement in information transparency in the banking industry has two effects on bank B's depositors. On the one hand, when the information about bank B is more precise, its depositors become more patient and are less likely to respond to information about other banks. On the other hand, when the information about other banks is more precise, it contains more information about bank B's assets, so depositors of bank B have a stronger incentive to respond to it.

How information transparency will affect the fragility of the banking industry depends on the relative sizes of these two effects.

Our model has empirical predictions. It suggests that contagious runs are more likely to occur to banks with poor information quality. It also implies that contagious runs are more likely to happen when the banking industry is weak. Our model has policy implications as well. It can be used to study the feasibility of using bank capital and deposit insurance to alleviate the contagious run problem. We demonstrate that both mechanisms can eliminate contagious runs without preventing efficient bank runs from happening. The ways they achieve this goal are different. While raising more bank capital increases the resources depositors can grab when a bank run occurs, deposit insurance reduces the number of depositors who withdraw early. We also show that, once contagious runs are eliminated by deposit insurance, an improvement in information transparency always improves depositor welfare. This result implies that, when a government requires banks to reveal more information, it should also adopt mechanisms that can induce depositors to use information efficiently.

In the literature, Cordella and Levy Yeyati (1998) show that full transparency of bank risks may increase the chance of a bank failure in case bank risk is chosen by nature. In their model, when depositors learn more information about their bank, the deposit rate offered by the bank becomes more sensitive to the state. As a result, the bank is more likely to fail in the riskier state because it has to pay a higher deposit rate in this state. Hyytinen and Takalo (2002) propose that the costs of information disclosure will reduce banks' charter values, thus increasing their risk-taking incentives. Complementing to these papers, this paper suggests another channel through which information transparency can affect banking fragility. By focusing on the depositors' responses to information, this paper can generate new policy implications.

The role of bank capital in our paper is similar to that in Gangopadhyay and Singh (2000). In both papers, bank capital is used to prevent inefficient bank runs. The two papers differ in the source of uncertainty. In Gangopadhyay and Singh (2000), the origin of uncertainty is the fraction of depositors who will die early, while in this paper the returns of banks' papers are random variables. The model and the deposit insurance system in this paper are similar to those in Chen (1999). A major difference between the two papers is that Chen (1999) assumes that informed depositors receive perfect information about bank returns, so his model cannot be used to study the impacts of information transparency on the stability of the banking industry. In addition, Chen (1999) does not discuss the possibility of using bank capital to eliminate contagious runs.

The rest of the paper is organized as follows. Section 2 describes the basic model. Section 3 shows that an improvement in information transparency may either increase or decrease the chance of a contagious run. Section 4 studies the role of bank capital in alleviating the contagious run problem. Section 5 demonstrates that contagious runs can also be eliminated by deposit insurance. Section 6 contains concluding remarks.

2. The Model

This is a three-date (dates 0, 1, and 2) model. There are two banks, banks A and B, located in different geographical areas; each bank is owned and controlled by its manager. For each bank, there are numerous potential depositors living the area where the bank is located. At date 0, each potential depositor receives an endowment of $1. A potential depositor can either deposit her endowment at the bank in her neighborhood, or stores the endowment herself. There are no storage costs if potential depositors store their endowments. Depositors face liquidity shocks. Some of them die at date 1, so have to consume before they die. The others die at date 2, and can consume at either date 1 or date 2. We will call those who die at date i type-i depositors, i = 1, 2. The fraction of type-1 depositors is denoted by t. The liquidity shocks are realized at date 1. At date 0, depositors do not know whether they will die early, and they have an equal chance of becoming type-1 depositors.

Depositors are risk-neutral. However, if a type-1 depositor consumes less than y at date 1, she will suffer a liquidity loss X, where y and X are constants with $y > 1$ and $X > 0$.[1] Let U_i denote the utility function of a type-i depositor, and c_j denote a depositor's consumption at date j. The depositors' utility functions can be written as

$$U_1(c_1,c_2) = \begin{cases} c_1 - X & \text{if } c_1 < y, \\ c_1 & \text{if } c_1 \geq y, \end{cases}$$

and $U_2(c_1,c_2) = c_1 + c_2$.

At date 0, each bank offers a deposit contract (d_1, d_2) to depositors in its

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[1] The purpose of making this assumption is to simplify the discussions on the optimal deposit contract. It allows us to concentrate on the depositors' response to public information about their banks.

neighborhood.[2] For each dollar deposited at date 0, the bank promises to pay d_1 if the depositor withdraws at date 1, and pay d_2 if the depositor withdraws at date 2. When serving depositors, banks cannot distinguish between type-1 and type-2 depositors. The sequential service constraint is imposed, which means depositors are served according to the time they arrive at the bank. For now, assume that banks do not have any capital, and there is no deposit insurance. We will relax these two assumptions in Sections 4 and 5, respectively. Convertibility suspension is not allowed. A bank has to keep open at date 1 unless it runs out of money. When determining the deposit contract, a bank's manager maximizes depositor welfare subject to the bank's zero-profit constraint.

For each bank, if potential depositors deposit their endowments at the bank at date 0, then the bank invests these endowments in a long-term paper that matures at date 2. Both banks' papers have the following features. The paper either succeeds or fails. For each dollar invested, a paper yields R if it succeeds and yields nothing if it fails. The probability that a bank's paper will succeed depends on the prospects of the banking industry. If the prospects are favorable, then the paper will succeed with probability p_g and will fail with probability $1 - p_g$. If the prospects are unfavorable, then the paper will succeed with probability p_b and will fail with probability $1 - p_b$. Both p_g and p_b are constants with $1 \geq p_g > p_b \geq 0.5$.[3] At date 0, the prior probability that the banking industry's prospects are favorable is θ. Let p_0 denote the date 0 probability that a bank's investment will succeed. We have

$$p_0 \equiv [\theta\, p_g + (1 - \theta)\, p_b]. \tag{1}$$

The paper can be liquidated at date 1; for each dollar invested at date 0, early liquidation yields one dollar. Assume that $p_0 R + (1 - p_0) > 1$, so the net present value of the paper is positive if it is continued to date 2 when it will succeed and is liquidated at date 1 when it will fail.

The two banks invest in different papers. Assume that, given the prospects of the banking industry, the returns of the two banks' papers are independent. Since both papers' probabilities of success are affected by the prospects of the banking industry, at date 0 the returns of the banks' papers are positively correlated. It is easy to show

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[2] Different banks may offer different deposit contracts. However, as mentioned below, we focus on the behavior of bank B's depositors. Therefore, we only study the deposit contract offered by bank B.

[3] The justification for assuming $p_b \geq 0.5$ is that, even during the Great Depression, only about one fifth of the banks in the United States failed. Therefore, it is not likely that the chance of a bank failure will exceed 0.5.

that the correlation coefficient between them is[4]

$$\rho \equiv \frac{\theta(1-\theta)(p_g - p_b)^2}{p_0(1-p_0)} > 0. \qquad (2)$$

If a bank invests at date 0, then a public signal about its paper will be revealed at date 1. Let s_A and s_B denote the public signals about bank A's and B's papers, respectively. For bank i, $i = A, B$, if bank i's paper will succeed, then $s_i = H$ with probability q_i and $s_i = L$ with probability $1 - q_i$, where q_i is a constant and $q_i \geq 0.5$. On the other hand, if Bank i's paper will fail, then $s_i = H$ with probability $1 - q_i$ and $s_i = L$ with probability q_i. The q_i can be explained as the precision of s_i; the larger the q_i, the more precise s_i is. All the depositors of the two banks can observe both signals when they are revealed. The public signals s_A and s_B are the only information depositors receive. That is, they cannot observe whether their banks' investment will fail, neither can they observe the prospects of the banking industry.

As mentioned above, both public signals and the depositors' liquidity shocks are revealed at date 1. For each bank, the signal about its paper and the liquidity shocks of its depositors are revealed simultaneously. To explore issues on contagious bank runs, we assume that s_A and the liquidity shocks of bank A's depositors are revealed first, and s_B and the liquidity shocks of bank B's depositors are revealed later. We will say that a contagious run occurs to bank B if the revelation of s_A triggers a bank run on bank B. In our model, a contagious run is inefficient because depositors of bank B forego the information about their own bank when they make the withdrawal decisions. We will study whether and when a contagious run will occur, and how it can be eliminated.

Given our focus on contagious runs, we will analyze only the behavior of bank B's depositors. The sequence of events about bank B is summarized as follows.

Date 0. Bank B's manager offers a deposit contract (d_1, d_2) to potential depositors in its neighborhood. Depositors decide whether to deposit their endowments.

Date 1. (i) Signal s_A is revealed. If depositors deposit their endowments at bank B

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[4] The variance of each bank's return is $p_0(1 - p_0)R^2$, and the covariance of the returns of the two banks' papers is $\theta(1 - \theta)(p_g - p_b)^2 R^2$. From these results, we can get the expression for ρ.

at date 0, then decide whether to withdraw.

(ii) Signal s_B and the liquidity shocks of depositors who live near to bank B are revealed. Depositors decide whether to withdraw if depositors deposit their endowments at bank B at date 0 and a contagious run does not occur when s_A is revealed.

Date 2. Bank B's paper matures if the investment is made at date 0 and the bank is not closed at date 1. Depositors who have not withdrawn at date 1 withdraw.

3. The Analysis of the Basic Model

Under our assumption that depositors cannot invest themselves, bank B can easily offer a deposit contract that gives depositors a strictly higher payoff than what they can get from storing the endowments themselves.[5] This means depositors always deposit their endowments at the bank in equilibrium. To simplify the exposition, we consider only the cases where the optimal deposit contract satisfies the depositors' liquidity needs, that is, the cases where $d_1 \geq y$. This condition implies that the amount a type-1 depositor gets is larger than the liquidation value of her deposits. As will be seen, this condition may induce depositors to have too much incentive to withdraw, thus leading to a contagious run.

Also, for simplicity, we study only symmetric pure-strategy subgame-perfect Nash equilibria.[6] Given this criterion, there are two equilibrium candidates in each date 1 subgame. For bank B, when a public signal (s_A or s_B) is revealed, either all depositors withdraw or no depositor withdraws. Also, we assume that depositors choose the Pareto dominant equilibrium when there are multiple equilibria.[7] As in Diamond and Dybvig (1983) and Chen (1999), it can be shown that (i) a bank run is always an equilibrium phenomenon in all the date 1 subgames, and (ii) a bank run is the Pareto dominated equilibrium when there are multiple equilibria.[8] Therefore, in our model a bank run will occur if and only if it is the only subgame-perfect Nash

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5 For example, he can set $d_1 = 1$ and $d_2 = R$. In this case, bank B serves as an agent who invests for depositors. Obviously, given $(d_1, d_2) = (1, R)$, depositors strictly prefer depositing to storing the endowments themselves.

6 That is, depositors of the same type will adopt the same pure strategy.

7 The purpose of making this assumption is to illustrate the point that information-based bank runs are still inefficient even if depositors choose the Pareto dominant equilibrium.

8 If 'no depositor withdraws' can be sustained as a Nash equilibrium in a date 1 subgame, the depositors' equilibrium payoff must be no lower than y. It can be shown that the depositors' expected payoff in the bank run equilibrium is strictly less than 1.

equilibrium. The equilibrium selection criterion we impose is not critical. All the main results hold if we assume there is a sunspot random variable that determines which equilibrium is realized in case of multiple equilibria.

The model is solved backwards. Sections 3.1 and 3.2 study the subgames when s_B and s_A are revealed, respectively. Section 3.3 determines the optimal deposit contract.

3.1 When s_B is revealed (at date 1)

First consider the subgame when s_B is revealed. Let $p_2(s_A, s_B)$ denote the probability that bank B's investment will succeed given s_A and s_B. Given s_B, the probability that bank B's paper will succeed is higher when $s_A = H$ than when $s_A = L$ because the two banks' returns are positively correlated. Therefore, we know that $p_2(L, L) < p_2(H, L)$ and $p_2(L, H) < p_2(H, H)$. In addition, we assume

$$P_2(H,L) < \frac{1}{R} < \frac{(1-t)y}{(1-ty)R} < p_2(L,H). \tag{3}$$

The assumption $p_2(H, L) < p_2(L, H)$ means that s_B contains more information about bank B's investment than s_A.[9] Assuming $p_2(H, L) < 1/R < p_2(L, H)$ implies that bank B's investment should be liquidated at date 1 if and only if $s_B = L$. To see this, note that given s_A and s_B, the continuation and liquidation values of bank B's per dollar investment are $p_2(s_A, s_B)\ R$ and 1, respectively. As a result, the paper should be liquidated if and only if $p_2(s_A, s_B) < 1/R$. Given (3), we have

$$p_2(L, L) < p_2(H, L) < \frac{1}{R} < p_2(L, H) < p_2(H, H),$$

which implies bank B's investment should be liquidated at date 1 if and only if $s_B = L$. The reason for assuming $P_2(H,L) < \frac{(1-t)y}{(1-ty)R} < p_2(L,H)$ will be explained in Section 3.3.

Suppose that no run has occurred to bank B yet before s_B and the liquidity shocks of bank B's depositors are revealed. When information about bank B arrives, type-1 depositors will withdraw. Whether type-2 depositors will withdraw depends on the updated probability that their bank's paper will succeed. For a type-2 depositor who believes that no other type-2 depositors will withdraw at date 1, her payoff for waiting

[9] Note that if q_A is high and q_B is low, then s_A may contain more information about bank B's investment than s_B. Condition (3) excludes this possibility.

until date 2 is $p_2(s_A, s_B)\, d_2$ and her payoff for withdrawing now is d_1. So, she will not withdraw if and only if $p_2(s_A,s_B)\, d_2 \geq d_1$, or

$$p_2(s_A, s_B) \geq \frac{d_1}{d_2}. \tag{4}$$

The no-run equilibrium can be sustained if and only if (4) holds. Therefore, if no bank run has occurred before s_B is revealed, then s_B will trigger a run on bank B if and only if (4) is violated.

3.2 When s_A is revealed (at date 1)

Now back to the time when s_A is revealed. Suppose that no depositor at bank B has withdrawn before information about bank A is revealed. Obviously no depositor will respond to s_A and withdraw if $s_A = H$. Now consider the case of $s_A = L$. If $d_1/d_2 \leq p_2(L, L)$, then by (4) a bank run will never occur when either s_A or s_B arrives. On the other hand, if $d_1/d_2 > p_2(L, H)$, then a contagious run will always occur when depositors of bank B learn that $s_A = L$.[10] Finally, consider the case where $p_2(L,L) < d_1/d_2 \leq p_2(L,H)$. Define

$$V_{BR}(d_1) \equiv 1 - \frac{d_1 - 1}{d_1} t X, \tag{5}$$

which is the depositors' expected payoff when a bank run occurs.[11] If $s_A = L$ and a depositor of bank B believes that all the other depositors will not withdraw before s_B is revealed, then her payoff for not responding to s_A is[12]

$$V_{Wait}(d_1, d_2) \equiv \pi\,[t\, d_1 + (1-t)\, p_2(L, H)\, d_2] + (1-\pi) V_{BR}(d_1), \tag{6}$$

where π is the conditional probability that $s_B = H$ given $s_A = L$. The depositor will respond to s_A and withdraw if $V_{Wait} < d_1$. Given our equilibrium selection criterion and (6), a low value of s_A will trigger a run on bank B if and only if $V_{Wait} < d_1$.

By equations (5) and (6), V_{Wait} is increasing in d_2 and is decreasing in d_1. There results are intuitive. When d_2 increases, a late withdrawer gets more if a bank run does

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[10] When $d_1/d_2 > p_2(L,H) > p_2(L,L)$ and $s_A = L$, the 'no depositor withdraws' equilibrium cannot be sustained whatever the value of s_B is. Therefore, all the depositors of bank B will withdraw once they learn $s_A = L$.

[11] Remind that we discuss only the cases where $d_1 \geq y > 1$. When a bank run occurs, some type-1 depositors cannot get their money from the bank, and have to suffer the liquidity loss X. The fraction of depositors who will suffer this loss is $t\,(1 - 1/d_1)$. Therefore, the depositors' expected payoff when a bank run occurs is $1 - t\,X\,(d_1 - 1)/d_1$.

[12] In this case, given $s_A = L$, a bank run will occur if and only if $s_B = L$. If $s_B = H$, only early diers withdraw at date 1, so the depositors' expected payoff is $t\,y + (1 - t)\, p_2(L, H)\, d_2$. If $s_B = L$, a bank run occurs, so the depositors' expected payoff is V_{BR}.

not occur at date 1, so a depositor's payoff for waiting until s_B is revealed increases. On the other hand, when d_1 increases, more type-1 depositors have to suffer the liquidity loss X in case a bank run occurs, so a depositor's payoff for waiting until s_B is revealed decreases.

3.3 When the deposit contract and bank capital are chosen (at date 0)

At date 0, the manager of bank B determines (d_1, d_2) to maximize depositor welfare subject to the bank's zero profit constraint. The following proposition states the optimal deposit contract and the equilibrium. The proofs of all the propositions and the lemma are available from the author upon request.

Proposition 1. Suppose that banks do not have capital, and that there is no deposit insurance.

(a) The optimal deposit contract $(d_1, d_2) = (y, d_{20})$, where

$$d_{20} \equiv \frac{(1-ty)R}{1-t}. \tag{7}$$

(b) When $s_A = L$, a contagious bank run occurs to bank B if and only if

$$\pi[ty + p_2(L,H)(1-ty)R] + (1-\pi)[1-(1-\frac{1}{y})tX] - y < 0. \tag{8}$$

The left hand side of (8) is increasing in q_B, p_g and p_b, and is decreasing in q_A.

Part (a) of Proposition 1 says that bank B will set d_1 just enough to cover type-1 depositors' liquidity needs. Increasing d_1 over y is never optimal because doing so not only increases the amount of early liquidation (which is not efficient since $p_0 R > 1$), but also induces depositors to have more incentive to withdraw early. The optimal d_2 in equation (7) follows from the bank's zero profit constraint. By (3),

$$p_2(H,L) < \frac{y}{d_{20}} = \frac{(1-t)y}{(1-ty)R} < p_2(L,H).$$

This means that given the deposit contract (y, d_{20}), if a contagious run does not occur, then a bank run will occur to bank B if and only if $s_B = L$. By the assumption that $P_2(H,L) < 1/R < p_2(L,H)$, such a bank run is efficient.

Part (b) of Proposition 1 states the conditions under which a contagious run will occur. It suggests that an improvement in information transparency may either raise or reduce the chance of a contagious bank run. To see this, note that both q_A and q_B

increase as banks disclose more precise information. When q_A is higher, s_A contains more information about the return of bank B's investment, so depositors of bank B have a stronger incentive to respond to s_A and withdraw. On the other hand, when q_B increases, s_B contains more information about bank B's investment, so depositors are more willing to wait until s_B arrives. Whether depositors of bank B will be more or less eager to respond to s_A depends on the relative sizes of these two effects. Part (b) of Proposition 1 predicts that banks with the least transparent information are likely to suffer a contagious run problem. It also implies that contagious runs are more likely to occur when the banking industry is weak (that is, when p_g and p_b are low).

4. Bank Capital and Contagious Runs

In the previous sections, we assume that banks do not have any capital. In this section, we study the possibility of using bank capital to solve the contagious run problem. Suppose that in addition to deposits, banks can also raise capital from the capital market. The required return for each dollar's capital between date 0 and date 2 is k, where $k > p_0R + (1 - p_0)$. This assumption implies that the required return of bank capital is higher than the expected return of the bank's paper. We will show that even in this case, bank B may still raise capital at date 0 if doing so allows it to eliminate contagious runs.

Let C denote the amount of capital that bank B raises at date 0.[13] Let $\hat{V}_{BR}$ and $\hat{V}_{Wait}$ denote V_{BR} and V_{Wait} when bank B can raise capital. We have[14]

$$\hat{V}_{BR}(d_1, C) \equiv \min\{d_1, 1 + C - \frac{d_1 - (1 + C)}{d_1} t X\}, \tag{9}$$

and

$$\hat{V}_{Wait}(d_1, d_2, C) \equiv \pi [t d_1 + (1 - t) p_2(L, H) d_2] + (1 - \pi) \hat{V}_{BR}(d_1, C). \tag{10}$$

The following lemma states the optimal deposit contract in this case.

Lemma. Let (d_1^*, d_2^*) denote the optimal (d_1, d_2) when bank B can raise capital.

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[13] When bank B raises capital, the new equity holders get all the shares of the bank, and the manager of the bank does not keep any share. However, the manager still controls the bank.

[14] If $1 + C \geq d_1$ and a bank run occurs, then bank B can pay off all the depositors and each depositor gets d_1. On the other hand, if $1 + C < d_1$ and a bank run occurs, some of type-1 depositors will suffer the liquidity loss X. The fraction of depositors who will suffer the loss X is $t [d_1 - (1+C)]/d_1$, so the depositors' expected payoff when a bank run occur becomes $1 + C - t X [d_1 - (1+C)]/d_1$ in this case. Equation (9) summarizes these results.

Then $d_1^* = y$, and

$$d_2^*(C) = d_{20} - \frac{k - p_0 q_B R}{(1-t) p_0 q_B} C. \tag{11}$$

The lemma says that, when bank B raises capital, the optimal d_1 is still y, and the optimal d_2 is a decreasing function of the amount of bank capital raised. The latter result follows from the bank's zero profit constraint.[15] Since capital is a costly source of funds, the bank has to reduce d_2 in response to an increase in C. Given the optimal deposit contract, the following proposition states the conditions under which using bank capital can eliminate contagious runs.

Proposition 2. Suppose that (8) holds, so without bank capital a contagious bank run will occur when $s_A = L$. Let $\pi_0(s_A, s_B)$ denote the prior probability that (s_A, s_B) will be observed, $s_A = H, L,$ and $s_B = H, L$. If there is a positive C^* that satisfies

(i) $\hat{V}_{Wait}(y, d_2^*(C^*), C^*) = y,$

(ii) $y / d_2^*(C^*) \leq p_2(L, H)$, and

(iii) $\pi_0(H,H)\, [t\, y+(1-t)\, p_2(H,H)\, d_2^*(C^*)] + \pi_0(L,H)\, [t\, y+(1-t)\, p_2(L,H)\, d_2^*(C^*)] +$

$[1 - \pi_0(H,H - \pi_0(L, H)]\ \hat{V}_{BR}(y, C^*) \geq \pi_0(H,H)[ty+(1-t)\, p_2(H,H) d_{20}] + [1 - \pi_0(H, H)]$

$\hat{V}_{BR}(y, 0)$,

then the optimal C is C^* and the optimal $(d_1, d_2) = (y, d_2^*(C^*))$. In this case, a contagious run never occurs, and a bank run occurs to bank B if and only if $s_B = L$.

Proposition 2 demonstrates how bank capital may help alleviating the contagious run problem. By (9), when bank B raises capital, there is more money left at bank at date 1, so more depositors can successfully withdraw when a bank run occurs. This reduces the depositors' incentive to rush to the bank. On the other hand, by (11) an increase in C results in a lower d_2, which will increase the depositors' incentive to respond to s_A. Taking these two effects together, an increase in C raises $\hat{V}_{Wait}$ if and only if

[15] When bank B can raise capital, our interpretation of the bank's zero-profit condition is: the manager of bank B gets nothing at date 2 after the new equity holders receive their returns.

$$\frac{d\hat{V}_{Wait}}{dC} = \frac{\partial \hat{V}_{Wait}}{\partial C} + \frac{\partial \hat{V}_{Wait}}{\partial d_2}\frac{dd_2^*}{dC} = (1-\pi)(1+\frac{tX}{y}) - \pi\, p_2(L,H)(\frac{k}{p_0 q_B} - R) > 0. \tag{12}$$

When (12) holds, we can find the C^* that satisfies condition (i) in Proposition 2. To prevent a contagious run from happening, $y/d_2^*(C^*)$ must be lower than $p_2(L, H)$ by condition (4). Condition (iii) in Proposition 2 requires that depositor welfare is higher when $C = C^*$ than when $C = 0$. If these conditions are satisfied, bank B will raise capital to eliminate contagious bank runs.

5. Deposit Insurance

In the past section, we show that the bank can raise bank capital to eliminate the contagious run problem. By increasing the depositors' payoff when a bank run happens, bank capital reduces their incentive to withdraw. One limitation of the mechanism proposed in Section 4 is that the results are sensitive to changes in assumptions. For example, if the number of signals that arrive before s_B is revealed is larger than 1 and these signals also contain information about bank B's investment, then the C^* proposed may not be sufficient to prevent contagious runs. In this section, we will design a mechanism that always induces depositors of bank B to wait until s_B is revealed even if multiple signals are revealed before s_B arrives.

An easy way to achieve this goal is to set $C = y - 1$. If $d_1 = y$ and $C = y - 1$, then at date 1 the bank always have enough money to pay off depositors even if all of them withdraw at date 1. Knowing this, depositors have no incentive to rush to the bank before s_B is revealed. However, since bank capital is a costly source of funds, setting $C = y - 1$ may be too costly for bank B. In this section, we will consider another alternative. We study the possibility of using deposit insurance to solve the contagious run problem.

The deposit insurance system considered in this section can be described as follows. Suppose that bank B randomly picks some of its depositors, and offer them deposit insurance that fully covers their losses. Let m denote the fraction of depositors who are insured. The remaining depositors (fraction $1 - m$) are uninsured. The deposit contract for the insured depositors is $d_1 = y$ and $d_2 = d_{2i}$, while the deposit contract for the uninsured depositors is $d_1 = y$ and $d_2 = d_{2u}$. The d_{2i} and d_{2u} will be determined endogenously. If the bank is unable to pay an insured depositor the amount it promises, the deposit insurer will pay the depositor.

Deposit insurance is not free. The bank has to pay the insurer an insurance premium at date 2 when no run occurs and its investment succeeds. Let κ denote the per dollar return required by the insurer. Assume that $\kappa > p_0 R + 1 - p_0$, which means that the required return for the deposit insurer is higher than the expected return of bank B's paper. Deposit insurance is fairly priced in the sense that the deposit insurer breaks even on average. For simplicity, assume that in this case the bank does not raise any capital, that is, $C = 0$.

After deposit insurance is offered, insured depositors withdraw at date 1 only when they become type-1 depositors, so the maximum fraction of depositors who withdraw at date 1 is

$m\,t + 1 - m$. To eliminate contagious runs completely, the bank has to make sure that depositors can still get d_1 if they withdraw at date 1 *after* s_B is revealed. This can be achieved if

$$(m\,t + 1 - m)\,d_1 \leq 1.$$

Using the fact that the bank will set $d_1 = y$ to cover type-1 depositors' liquidity needs, m has to satisfy

$$m \geq m_0 \equiv \frac{1 - 1/y}{1 - t}. \tag{13}$$

From the assumption that $\kappa > p_0 R + 1 - p_0$, the bank will minimize the size of the insured depositors, so he will set m equal to m_0.

Obviously, given deposit insurance the optimal $d_1 = y$. We next determine the optimal deposit contracts. The d_{2i} and d_{2u} have to satisfy two constraints. First, the deposit insurance system has to be fairly priced. Given the fact that contagious runs are eliminated by deposit insurance, this condition is equivalent to

$$\kappa(1 - p_0 q_B) m_0 (1 - t) d_{2i} = p_0 q_B [(1 - ty)R - m_0(1 - t)d_{2i} - (1 - m_0)(1 - t)d_{2u}]. \tag{14}$$

The left hand side of (14) is the costs of deposit insurance,[16] and the right hand side is the bank's expected profit before it pays the insurance premiums. By the bank's

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[16] Given (3) and the fact that there is no contagious run when deposit insurance is offered, the probability that the bank can pay off its depositors at date 2 is $p_0\, q_B$. When the bank is unable to pay off the insured depositors at date 2, the deposit insurer has to pay them. Therefore, the insurer's expected payment is

$$(1 - p_0\, q_B)\, m_0\, (1 - t)\, d_{2i}.$$

The κ in (14) is the deposit insurer's required return.

zero-profit condition,[17] all of the bank's profit will be used to pay the deposit insurer. Therefore, (14) should hold.

The second constraint that d_{2i} and d_{2u} have to satisfy is that the insured and uninsured depositors should have the same expected payoff at date 0, otherwise the depositors with the lower expected payoff will complain about the unfairness. This constraint can be written as

$$ty + (1-t)d_{2i} = t\,y + (1-t)\left\{p_0 q_B d_{2u} + [\,p_0(1-q_B) + (1-p_0)q_B\,]\,y\right\}. \tag{15}$$

The left hand side of (15) is the insured depositors' expected payoff, and the right hand side is the uninsured depositors' expected payoff.[18] Using (14) and (15), we can get the optimal d_{2i} and d_{2u}. The following proposition documents the results.

Proposition 3. Let (d_{2i}^*, d_{2u}^*) denote the (d_{2i}, d_{2u}) that satisfies (14) and (15). The above deposit insurance system eliminates contagious runs if and only if

$$p_2(H,L) \le \frac{y}{d_{2u}^*} \le p_2(L,H)\,. \tag{16}$$

When (16) holds, depositor welfare is independent of q_A and is increasing in q_B.

In Proposition 3, condition (16) guarantees that the uninsured depositors will withdraw at date 1 if and only if $s_B = L$. An interesting result of Proposition 3 is that, once the contagious run problem is solved by deposit insurance, an improvement in information transparency always improves depositor welfare. This result suggests that, with an adequately designed deposit insurance system, imposing a stricter information disclosure rule in the banking industry is always welfare improving.

The deposit insurance system stated in this section is very similar to that in Chen (1999). It has two attractive features. First, while contagious runs are eliminated by this system, an efficient bank run still occurs when $s_B = L$. Therefore, this deposit insurance system does not sacrifice market discipline. Second, the deposit insurance system is robust. Given this system, an uninsured depositor's payoff is independent of

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[17] When deposit insurance is offered, our interpretation of the bank's zero-profit condition is: the manager of bank B gets nothing at date 2 after he pays the insurance premiums.

[18] In (15), $p_0\, q_B$ is the probability that the uninsured depositors get paid at date 2, and [$p_0(1-q_B) + (1-p_0)\, q_B$] is the probability that a bank run occurs because $s_B = L$. The uninsured type-1 depositors always get y, and the uninsured type-2 depositors get d_{2u} with probability $p_0\, q_B$ and gets y with probability [$p_0(1-q_B) + (1-p_0)\, q_B$]. With probability $(1-p_0)(1-q_B)$, $s_B = H$ but bank B's investment fails. The uninsured type-2 depositors get nothing in this case.

other depositors' actions; she gets y if she withdraws at date 1, and gets d^*_{2u} if she withdraws at date 2 and the bank's paper succeeds. The payoff externalities among depositors disappear, so the uninsured depositors will use their information efficiently at date 1. This implies that, even if multiple signals that contain information about bank B's paper are revealed before s_B arrives, uninsured depositors will never withdraw before they observe s_B.

6. Concluding Remarks

In this paper, we show that an improvement in information transparency in the banking industry may either increase or decrease the chance of contagious runs. We also discuss the possibility of using bank capital and deposit insurance to alleviate the contagious run problem. To focus on how depositors respond to information, in this paper we assume that bank risk is exogenously determined. In the real world, bank managers have great impacts on the choice of bank risk. In the banking literature, many papers discuss how to design regulation policies to reduce bank managers' risk-taking behavior.[19] If we change the assumption and assume that bank risk is chosen by bank managers, our model will have implications on how information transparency affects bank managers' risk-taking behavior. We expect that, if the contagious run problem can be solved, more information transparency will reduce the bank managers' incentives to pursue unsound risks. This is because the threat of bank runs can discipline banks: the more risk a bank manager takes, his bank will be subject to a higher chance of a bank run. When depositors have more precise information, this disciplining effect will be stronger, so bank managers will have less incentive to pursue risks.

[19] For example, see Cordella and Levy Yeyati (1998, 2002), Hellmann, Murdock, and Stiglitz (2000), and Matutes and Vives (1996, 2000).

參考文獻

Calomiris, C.W., and J.R. Mason, 1997, Contagion and bank failures during the great depression: the June 1932 Chicago banking panic, American Economic Review 87, 863-883.

Calomiris, C.W., 1990, Is deposit insurance necessary? A historical perspective, Journal of Economic History 50, 283-295.

Calomiris, C.W., and C.M. Kahn, 1991, The role of demandable debt in structuring optimal banking arrangements, American Economic Review 81, 497-513.

Calomiris, C.W., and G. Gorton, 1991, The origins of banking panics: models, facts, and bank regulation, in R. G. Hubbard, Eds., Financial markets and financial crises (University of Chicago Press, Chicago), 109-173.

Chari, V.V., and R. Jaganathan, 1988, Banking panics, information, and rational expectations equilibrium, Journal of Finance 43, 749-761.

Chen, Y., 1999, The role of the first come, first served rule and information externalities, Journal of Political Economy 107, 946-968.

Cordella, T., and E. Levy Yeyati, 1998, Public Disclosure and Bank Failures, IMF Staff papers 45, 110-131.

Cordella, T., and E. Levy Yeyati, 2002, Financial Opening, Deposit Insurance, and Risk in a Model of Banking Competition, European Economic Review 46, 471-485.

Diamond, D.W. and P.H. Dybvig, 1983, Bank runs, deposit insurance and liquidity, Journal of Political Economy 91, 401-419.

Gangopadsyay, S., and G. Singh, 2000, Avoiding Bank Runs in Transition Economies: the Role of Risk Neutral Capital, Journal of Banking and Finance 24, 625-642.

Gorton, G., 1985, Bank suspension of convertibility, Journal of Monetary Economy 15, 177-193.

Hellmann, T.F., K.C. Murdock, and J.E. Stiglitz, 2000, Liberalization, Moral Hazard in Banking and Prudential Regulation: Are Capital Requirements Enough?, American Economic Review 90, 147-165.

Hyytinen, A., and T. Takalo, 2002, Enhancing Bank Transparency: A Re-assessment, European Financial Review 6, 429-445.

Jacklin, C.J., and S. Bhattacharya, 1988, Distinguishing panics and information-based bank runs: welfare and policy implications, Journal of Political Economy 96, 568-592.

Matutes, C., and X. Vives, 1996, Competition for Deposits, Fragility, and Insurance, Journal of Financial Intermediation 5, 184-216.

Matutes, C., and X. Vives, 2000, Imperfect Competition, Risk Taking, and Regulation in Banking, European Economic Review 44, 1-34.

Miron, J.A., 1986, Financial panics, the seasonality of the nominal interest rate, and the founding of the Fed, American Economic Review 76, 125-140.

Mishkin, F.S., 1991, Asymmetric information and financial crises: a historical perspective, in R. G. Hubbard, Eds., Financial markets and financial crises (University of Chicago Press, Chicago), 69-108.

Park, S., 1991, Bank failure contagion in historical perspective, Journal of Monetary Economy 28, 271-286.

Postlewaite, A., and X. Vives, 1987, Bank runs as an equilibrium phenomenon, Journal of Political Economy 95, 485-491.

計畫自評

This project has achieved most of the goals stated in the original research proposal. It has two main contributions to the literature. First, it develops a simple theoretical model of bank runs. In the literature, most bank run papers model the depositors' liquidity needs by assuming that depositors are risk averse and some of them will early so have to consume early. The risk-averse assumption makes it difficult to find the optimal deposit contract or to study the depositors' response to information. In contrast, this project assumes that depositors are risk neutral. However, some of them will suffer a liquidity loss if their consumptions before a deadline are less than a critical level. This setting greatly simplifies the model without sacrificing the reasonableness of the model. Given the setting, the optimal deposit contract becomes obvious, and it is easy to study the depositors' response to information. As a result, it allows us to investigate policy issues more carefully.

The second contribution of the project is that it studies various policy issues related to bank runs. It investigates not only how convertibility suspension can improve the efficiency of bank runs, but also the design of bank information transparency regulations when contagious bank runs are a serious concern. In addition, it discusses how bank capital regulations and deposit insurance affect the depositors' withdrawing decisions. Although these policies have been studied by other papers in the literature, the simplicity of the model allows this project to find new results. Among the policy implications of this project, those related to convertibility suspension and bank information transparency are original and interesting. I expect that the two papers of this project can be published in academic journals.