Yehning Chen – Iftekhar Hasan

Why do bank runs look like panic? A new explanation

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Why do bank runs look like panic? A new explanation

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Abstract

This paper demonstrates that, even if depositors are fully rational and always choose the Pareto dominant equilibrium when there are multiple equilibria, a bank run may still occur when depositors' expectations of the bank's fundamentals do not change. More specifically, a bank run may occur when depositors learn that noisy bank-specific information is revealed, or when they learn that precise bank-specific information is not revealed. The results in this paper are consistent with empirical evidence about bank runs. It also implies that suspension of convertibility can improve the efficiency of bank runs.

Key words: bank run, banking panic, suspension of convertibility

JEL classification numbers: G21, G28

Ilmentävätkö talletuspaot tallettajien pakokauhua vai rationaalista käyttäytymistä? Uuden teorian tarkastelua

Suomen Pankin tutkimus
Keskustelualoitteita 19/2006

Yehning Chen – Iftekhar Hasan
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tässä tutkimuksessa osoitetaan, että rationaalisesti käyttäytyvien ja monesta mahdollisesta parhaan tasapainon valitsevien tallettajien tapauksessakin talletuspako pankeista on mahdollinen, kun tallettajien käsitykset pankkien talouden perustekijöistä ei muutu. Täsmällisemmin ilmaisten talletuspako on mahdollinen, kun tallettajat saavat puutteellista pankkikohtaista tietoa tai kun heille selviää, ettei heille paljasteta täsmällistä pankkikohtaista tietoa. Työn tulokset ovat sopusoinnussa talletuspakoja koskevan empiirisen näytön kanssa. Analyysista seuraa myös, että valuutan vaihdettavuuden lykkääminen lisää tallettajien hyvinvointia.

Avainsanat: talletuspako, pankkipaniikki, vaihdettavuuden lykkääminen

JEL-luokittelu: G21, G28

Contents

1 Introduction

Even though most empirical studies conclude that bank runs are associated with adverse information about banks,[1] the view that bank runs are caused by depositor panic is still popular because some features of bank runs cannot be fully explained by negative bank-specific information. For example, during large scale bank runs depositors usually do not distinguish between good and bad banks; they rush to all banks to withdraw deposits. An example is the 1932 Chicago Banking Crisis.[2] During the first week of that crisis (late June of 1932), massive withdrawals occurred from all banks in Chicago. Since it is unlikely that all the banks in Chicago were in terrible financial conditions that deserved a bank run, it is fair to say that during this crisis some banks in Chicago suffered runs even if they appeared sound.[3] Runs occurring to these banks may look more like depositor panic rather than the rational response of depositors to negative bank-specific information.

In this paper, we propose a new theory to explain why bank runs look like a panic. We define a panic run as a bank run that occurs when depositors' expectations of the bank's fundamentals do not change. In our model, panic runs are triggered by changes in depositors' expectations of the bank-specific information process. More specifically, depositors may start a run when they expect that more noisy information about banks will be revealed, or when they expect that precise information about banks will not be revealed. We show that panic runs can occur even if depositors are fully rational and always choose the Pareto dominant equilibrium when there are multiple equilibria.

The intuition of our model can be explained as follows. Consider a bank that collects deposits to invest in risky assets. Suppose that depositors demand liquidity and the bank provides it by allowing early withdrawing depositors to consume more than the liquidation values of their deposits. Moreover, depositors may receive an interim signal about the return on the bank's assets.

In this setting, whether information-based bank runs can improve depositor welfare depends on the quality of the signal about bank assets. If the signal is relatively precise, information-based runs are beneficial because they can serve as a mechanism to efficiently liquidate the bank when its continuation value is lower than the liquidation value. On the other hand, if the signal is informative[4] but

[1] For example, see Calomiris and Mason (1997, 2003), Hasan and Dwyer (1994), Mishkin (1991), Saunders and Wilson (1996), and Schumacher (2000).

[2] For an excellent investigation of the 1932 Chicago banking crisis, please see Calomiris and Mason (1997).

[3] As mentioned in p. 886 in Calomiris and Mason (1997), the Commercial and Financial Chronicle (July 2, 1932, 70–71) specifically noted that even healthy banks such as First Chicago were also affected by this event.

[4] That is, it can trigger a bank run when its realized value infers bad news about the bank.

relatively noisy, then information-based runs will reduce depositor welfare. As shown in Chen and Hasan (2006), a deposit contract that provides liquidity will induce depositors to have excessive incentives to withdraw. The excessive incentives to withdraw may force depositors to respond to mildly adverse information about the bank and start a bank run even if they would be better off if the run did not happen.

The above results help explain why panic runs occur. At any point in time after they deposit, depositors can decide whether to withdraw immediately or to wait, and a bank run will occur when the depositors' expected payoff for waiting is lower than what they can receive from successfully withdrawing. When depositors learn that a relatively noisy (but still informative) signal will be revealed, they realize that a welfare decreasing bank run is more likely to occur, so their payoff for waiting becomes lower. Similarly, when depositors learn that a precise signal will not be revealed, they realize that they will not be able to use the signal for triggering a welfare improving bank run, so their payoff for waiting also becomes lower. In both cases, the reduction in depositors' expected payoff for waiting may lead to a panic run.

In a more general sense, our results illustrate that information not only has the direct effect of changing posteriors, but also has the indirect effect of moving players along the game tree and affecting backwards induction calculations.[5] As the information structure changes, depositors know that they will face different situations in the future, so their incentives to withdraw also change. Therefore, a bank run can happen even if depositors' beliefs about the bank's financial condition does not change.

The model has several interesting implications. First, panic runs are more likely to occur when the prospects of the banking industry are poor, since when the prior probability of a bank failure is higher, the depositors' payoff from waiting to withdraw is lower. This result is consistent with the empirical evidence that large scale bank runs usually follow adverse information about banks.

Second, during bad times for banks, a bank whose financial condition does not appear weak may experience a panic run. As the health of the banking industry becomes the focus of public attention, more bank-specific information is likely to be revealed in the media. Even if a bank's fundamentals appear sound, concern that more noisy bank-specific information will be revealed may lead depositors to exit. This provides an explanation for why bank runs occur to all banks rather than to only bad ones during large scale banking crises.

Third, our model implies that suspension of convertibility can raise depositor welfare. When a panic run occurs, suspension of convertibility forces depositors to delay their withdrawal decisions until more information is revealed, so fewer solvent banks will be liquidated. This prediction is consistent with the result in

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[5] We are grateful to an anonymous referee for pointing out the general intuitions of our results.

Dwyer and Hasan (2006) that suspension of payments reduces the probability of a bank closure by twenty five percent.

Our paper is related to the classical work of Diamond and Dybvig (1983) (DD), who interpret a bank run as the result that depositors choose a Pareto dominated equilibrium. As in DD, in our model panic runs can occur and suspension of convertibility can alleviate the panic run problem.[6] However, the empirical implications are different. While a panic run in DD can happen randomly, our model predicts that panic runs are more likely to occur when the banking industry is weaker. Also, the ways that suspension of convertibility alleviates the panic run problem differ. In DD, suspension of convertibility ensures that enough resources will be reserved in the bank for depositors who withdraw late. Knowing this, depositors without liquidity needs will not withdraw early. In contrast, in our model suspension of convertibility eliminates panic runs by forcing depositors to delay their withdrawal decisions until more information is revealed.

In terms of model setting and basic ideas, this paper is similar to Chen (1999) and Chen and Hasan (2006). It extends that framework to show that a bank run can be triggered not only by bank-specific information, but also by depositors' expectations about the amount and quality of bank-specific information that will be revealed. Chari and Jagannathan (1988) also study bank runs and suspension of convertibility, but the bank runs in their paper are information driven, so do not fit our definition of panic runs.

Finally, Goldstein and Pauzner (2005) establish a model in which depositors receive private noisy information about bank assets, and demonstrate that fundamentals about banks can *uniquely* determine whether a bank run occurs. They define a panic run as a bank run that occurs despite the fact that no agent would have run if he believed no other agent was going to run. The panic run in our paper differs from theirs. In our model, a panic run occurs even if bank fundamentals do not change, while panic runs in their model are information driven. Also, in our model the depositors' withdrawal decisions during a panic run will not be affected by their belief about others' strategies. That is, they would withdraw even if they believed that all the others (except those with liquidity needs) would not withdraw.[7] In contrast to Goldstein and Pauzner who emphasize that bank runs can still be explained as panic-based when the equilibrium is uniquely determined, we focus on how changes in the information structure lead to panic runs. The two definitions capture important but different features of panic bank runs.

[6] In DD, the bank's investment is risk free, so its fundamentals never change. Therefore, the bank run in their paper fits our definition of a panic run (that is, a bank run that occurs even if depositors' expectations of the bank's fundamentals do not change).

[7] We have this result because we assume that depositors choose the Pareto dominant equilibrium when there are multiple equilibria. For more detail, please see the analysis 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. Concluding remarks are in Section 4.

2 The model

This is a three-date (dates 0, 1, and 2) model. There are numerous atomistic depositors and one bank. At date 0, each depositor receives an endowment of one dollar. A depositor can either deposit the endowment at the bank, or invest it in a long-term divisible project that matures at date 2. For each dollar invested, the project yields R with probability p and nothing with probability 1 – p, where p is a random variable and $p = p_0$ at date 0. Assume that $p_0\ R > 1$, so the project's expected rate of return is positive. The project can be liquidated at date 1. For each dollar invested at date 0, liquidation yields one dollar at date 1. For simplicity, assume that the returns on all the long-term projects are perfectly correlated.

Some depositors face liquidity shocks and have to consume at date 1. The others can consume at either date 1 or date 2. Depositors of type i must consume by date i (i = 1,2). The proportion of type-1 depositors is t, where t is a constant. At date 0, depositors are symmetric: they do not know their types, and each of them has the same probability of becoming a type-1 depositor. Depositors learn their types at date 1. Depositors are risk neutral. However, a type-1 depositor that consumes less than r at date 1 suffers a liquidity loss in utility, X, where r and X are constants with r > 1 and X > 0. Let U_i denote the utility function of a type-i depositor, and c_j denote the depositor's consumption at date j. The depositors' utility functions can be written as

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

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

At date 1, depositors may receive a public signal, s, about p. At date 0, it is common knowledge that s will be revealed with probability α and will not be revealed with probability $1 - \alpha$, where α is a constant. The value of s is either H or L. If the return on the projects will be R, then s = H with probability q and s = L with probability 1 – q; if the return on the long-term projects will be 0, then s = H with probability 1 – q and s = L with probability q, where $0.5 \leq q \leq 1$ and q reflects the precision of the signal. Let p_H and p_L denote the probabilities that the projects' return is R given s = H and s = L, respectively. Then

$$p_L(p_0,q) \equiv \frac{p_0(1-q)}{p_0(1-q)+(1-p_0)q} \leq p_0 \leq p_H(p_0,q) \equiv \frac{p_0 q}{p_0 q+(1-p_0)(1-q)} \qquad (2.1)$$

By equation (2.1), p_H is increasing in q and p_L is decreasing in q.

We divide date 1 into two consecutive subdates: subdates 1.1 and 1.2. At subdate 1.1, depositors learn whether s will be revealed at subdate 1.2. Depositors also learn their types at subdate 1.2. They learn their type and the value of s simultaneously when s is revealed.

A type-1 depositor who invests independently has to liquidate the project at date 1 and suffer the liquidity loss. Hence, the existence of a bank may improve depositor welfare. At date 0, the bank collects money from depositors and invests the proceeds in the project; it also offers a deposit contract (d_1, d_2) to depositors. For each dollar deposited, the bank promises to pay d_1 if the depositor withdraws at any subdate of date 1, and pay d_2 if the depositor withdraws at date 2 after the bank's investment matures.[8]

When depositors withdraw, the bank cannot distinguish between type-1 and type-2 depositors and depositors are sequentially served. There is no deposit insurance. The banking industry is competitive, so the bank's expected profit is zero. For now, we assume that suspension of convertibility is not allowed, so the bank has to open at date 1 unless it runs out of money. Finally, we assume that the parameter values satisfy

$$t < \min\left\{\frac{R-r}{rR-r}, \frac{1}{r+(1-1/r)X}\right\} \qquad (2.2)$$

The reasons for requiring (2.2) will become clear in the next section.

[8] In this paper, we do not consider more sophisticated deposit contracts, such as contracts in which payouts can be contingent on the public signal. We do so because it is difficult to enforce these more sophisticated contracts in practice.

3 The analysis of the model

This section establishes conditions under which a bank run will occur. For simplicity, assume that the bank sets $(d_1, d_2) = (d_1^*, d_2^*)$, where[9]

$$(d_1^*, d_2^*) \equiv (r, \frac{(1 - t\,r)R}{1 - t}). \tag{3.1}$$

Note that by (2.2), $t < (R - r)/(r\,R - r)$, which implies d_1^* is strictly less than d_2^*. If $d_1 \geq d_2$, all depositors would withdraw at date 1.

The game is solved backwards. To simplify exposition, we study only symmetric pure-strategy subgame-perfect Nash equilibria. Given this criterion, there are two equilibrium candidates in each date 1 subgame. At subdates 1.1, either all depositors withdraw or no depositor withdraws. At subdate 1.2, either all depositors withdraw or only type-1 depositors withdraw. We will say that a bank run occurs if all depositors withdraw at any subdate of date 1. Also, we assume that depositors choose a Pareto Dominant equilibrium when there are multiple equilibria.[10] As in DD and Chen (1999), a bank run can always be sustained as an equilibrium, and it is always Pareto dominated when there are multiple equilibria.[11] Therefore, in our model a bank run occurs if and only if it is the only subgame-perfect Nash equilibrium.[12]

A bank run that occurs at subdate 1.1 is a panic run since no new information about the bank's project has been revealed yet. To show that a bank run may occur at subdate 1.1, we first consider the subgame of subdate 1.2. Suppose that

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[9] It can be shown that (d_1^*, d_2^*) is the optimal deposit contract when providing liquidity is an important concern for designing the deposit contract. To allow type-1 depositors to avoid liquidity losses, the bank must set $d_1 \geq r$. However, setting $d_1 > r$ is not optimal for two reasons. First, the higher is the d_1, the less money the bank can invest in the profitable long-term project. Second, given $d_1 > 1$ and $d_2 < R$, depositors have excessive incentives to withdraw at date 1. An increase in d_1 will worsen this problem. Therefore, the optimal d_1 is r. Given $d_1 = r$, the bank's zero-profit condition implies $d_2 = d_2^*$.

[10] 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 Dominant equilibrium.

[11] 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 (3.3) below, which is strictly less than 1.

[12] If the bank's payouts can be contingent on the public signal, the optimal deposit contract and the equilibrium may change. In this case, one contract that may dominate (d_1^*, d_2^*) is: $(d_1, d_2) = (d_1^*, d_2^*)$ when $s = H$, and $(d_1, d_2) = (1, R)$ when $s = L$. Intuitively, this signal-contingent deposit contract allows the bank to stop providing liquidity when an inefficient bank run is a concern (that is, when $s = L$). It can be shown that this contract dominates (d_1^*, d_2^*) if $t\,(1 - X) + (1 - t)\,p_L\,R$ is larger than V_{BR} defined in equation (3.3). We are grateful to D. Lucas (editor) for pointing out that (d_1^*, d_2^*) may not be optimal when payouts can be contingent on s.

no depositor has withdrawn at subdate 1.1. At subdate 1.2, type-1 depositors will withdraw. The type-2 depositors' incentives to withdraw depend on their belief about others' strategies. Given the realization of p,[13] if a type-2 depositor believes that no other type-2 depositors will withdraw, his payoffs for withdrawing and for not withdrawing are $d_t^* = r$ and pd_2^*, respectively. Therefore, 'only type-1 depositors withdraw' can be sustained as an equilibrium if and only if $pd_2^* \geq d_1^*$, or

$$p \geq p_N \equiv \frac{(1-t)r}{(1-tr)R} \tag{3.2}$$

Hence, a bank run will occur if and only if $p < p_N$.

Note that a bank run that occurs at subdate 1.2 may be inefficient. When a bank run occurs at subdate 1.2, depositor welfare is[14]

$$V_{BR} \equiv t\left[\frac{1}{d_1^*}d_1^* + \left(1-\frac{1}{d_1^*}\right)(-X)\right] + (1-t)\frac{1}{d_1^*}d_1^* = 1 - \left(1-\frac{1}{r}\right)tX \tag{3.3}$$

Because $r > 1$ and $V_{BR} < 1$, we know that $V_{BR} < r$. On the other hand, given p, depositor welfare when a bank run does not occur at subdate 1.2 is

$$V_{NW}(p) \equiv t d_1^* + (1-t) p d_2^* = tr + (1-tr)pR \tag{3.4}$$

If depositors could coordinate to maximize their joint welfare, they would start a bank run if and only if $V_{NW}(p) < V_{BR}$, or equivalently

$$p < p^* \equiv \frac{1-(1-1/r)tX - tr}{(1-tr)R} \tag{3.5}$$

By (2.2), the p* defined in (3.5) is strictly positive, so a bank run improves depositor welfare when p is sufficiently low. It can be easily shown that $p^* < p_N$.[15] Therefore, when $p^* < p < p_N$, a bank run occurs even if depositors would be better off if it did not happen.

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[13] Depending on whether s is revealed, the value of p may be p_0, p_H, or p_L.

[14] In (3.3), t and (1–t) are the proportions of type-1 and type-2 depositors, respectively; $1/d_1^*$ and $(1 - 1/d_1^*)$ are the fractions of depositors who successfully withdraw and who go to the bank after the bank runs out of money, respectively.

[15] $V_{NW}(p) < r$ if and only if $p < p_N$. Since $V_{BR} < r$ and V_{NW} is increasing in p, we know that $p^* < p_N$.

Depositors have excessive incentives to withdraw in our model for two reasons. First, to provide liquidity, the bank has to set $d_1 = r > 1$ and $d_2 < R$,[16] which means depositors receive more than the liquidation values of their deposits if they withdraw at date 1, and do not receive the full return of the investment if they withdraw at date 2. Second, given $d_1 > 1$, some depositors lose their deposits when a bank run occurs; these depositors will suffer the liquidity loss X if they become type-1 depositors. However, when deciding whether to withdraw, depositors do not take the liquidity losses of other depositors into consideration.

To simplify exposition, in the rest of the paper we consider only the case where the signal is informative, that is

$$p_L(p_0, q) < p_N < p_H(p_0, q) \tag{3.6}$$

Equation (3.6) implies that, if depositors wait until subdate 1.2 and s is revealed, a bank run occurs only when s = L.

Now consider subdate 1.1, when depositors learn whether s will be revealed at subdate 1.2. If s will not be revealed, a bank run occurs at subdate 1.1 if and only if $p_0 < p_N$. If s will be revealed, the depositors' payoff for waiting until subdate 1.2 becomes

$$V_M(p_0, q) \equiv \pi_H V_{NW}(p_H(p_0, q)) + (1 - \pi_H) V_{BR} \tag{3.7}$$

where $\pi H \equiv p_0 q + (1 - p_0)(1 - q)$ is the prior probability of the event s = H. Then a bank run will occur at subdate 1.1 if and only if $V_M(p_0, q) < r$. Let $p_M(q)$ denote the p_0 that satisfies $V_M(p_0, q) = r$. Since V_M is strictly increasing in p_0, the condition $V_M(p_0, q) < r$ is equivalent to $p_0 < p_M(q)$. The above results establish the following proposition.

Proposition 1. Suppose that depositors deposit at date 0.

(a) At subdate 1.1, if depositors learn that s will not be revealed, depositor welfare is

$$W_N(p_0) \equiv \begin{cases} V_{NW}(p_0) & \text{if } p_0 \geq p_N, \\ V_{BR} & \text{if } p_0 < p_N. \end{cases} \tag{3.8}$$

In this case, a panic run occurs at subdate 1.1 if and only if $p_0 < p_N$.

[16] Note that $d_1 \geq r$ is a necessary condition for the deposit contract to Pareto dominate self-investing for depositors. Later in this section, we will show the condition under which depositors are better off when the bank is formed. This condition justifies why the bank sets $d_1 = r$ even if doing so may lead to inefficient bank runs.

(b) At subdate 1.1, if depositors learn that s will be revealed, depositor welfare is

$$W_S(p_0,q) \equiv \begin{cases} V_M(p_0,q) & \text{if } p_0 \geq p_M(q), \\ V_{BR} & \text{if } p_0 < p_M(q). \end{cases} \tag{3.9}$$

In this case, a panic run occurs at subdate 1.1 if and only if $p_0 < p_M(q)$.

Proposition 1 states that a panic run will occur when p_0 is low. This result is intuitive. The lower is p_0, the lower the depositors' payoff for waiting until subdate 1.2 is, so depositors have a stronger incentive to withdraw at subdate 1.1. As mentioned, this result is consistent with the observation that large scale bank runs follow negative information about banks.

At date 0, savers will use banks if the payoff from doing so is higher than from self-investing. The depositor's expected payoff for self-investing is[17]

$$V_0 \equiv t(1-X) + (1-t)\{\alpha[\pi_H p_H R + (1-\pi_H)\max\{1, p_L R\}] + (1-\alpha) p_0 R\}. \tag{3.10}$$

On the other hand, the payoff from depositing is $\alpha W_S(p_0,q) + (1-\alpha) W_N(p_0)$. We assume that

$$\alpha W_S(p_0,q) + (1-\alpha) W_N(p_0) > V_0 \tag{3.11}$$

so depositors will make deposits at date 0. It can be easily shown that (3.11) will hold when X is high so providing liquidity to type-1 depositors is an important concern.[18] We also assume that

$$\alpha W_S(p_0,q) + (1-\alpha) W_N(p_0) > r \tag{3.12}$$

which implies that a bank run will not occur at subdate 1.1 before depositors learn whether s will be revealed.

We next study how the precision of the public signal s affects depositors' behavior. The results are summarized in the following proposition.

[17] If a depositor becomes a type-1 depositor, his payoff is 1 – X. If a depositor becomes a type-2 depositor and s will be revealed, s is used to determine whether to liquidate the project. Along with the assumption that $p_0 R > 1$, we have (3.10).

[18] Intuitively, if a depositor self-invests, he will suffer X with probability one when he turns out to be a type-1 depositor. On the other hand, if he makes deposits and becomes a type-1 depositor, he suffers X only when (i) a bank run occurs, and (ii) he cannot successfully withdraw from the bank (the probability of this event is 1 – 1/r given that a bank run occurs). Therefore, (3.11) holds when X is high.

Proposition 2.

(a) If the signal is informative but relatively noisy, depositors are more eager to withdraw when they learn that the signal will be revealed. If the signal is informative and relatively precise, depositors are more eager to withdraw when they learn that the signal will not be revealed. That is, there exists a q_C in the range (0.5, 1) such that $p_M(q) > p_N$ if $q < q_C$, and $p_M(q) < p_N$ if $q > q_C$.

(b) When the signal is informative but relatively noisy, a panic run occurs at subdate 1.1 if $p_N < p_0 < p_M(q)$ and depositors learn that the signal will be revealed. When the signal is relatively precise, a panic run occurs at subdate 1.1 if $p_M(q) < p_0 < p_N$ and depositors learn that the signal will not be revealed.

Proof. See Appendix.

Proposition 2 can be explained as follows. From the above analysis, when s will be revealed and no depositor withdraws at subdate 1.1, a welfare decreasing bank run will occur at subdate 1.2 if and only if s = L and

$$p^* < p_L(p_0, q) < p_N \tag{3.13}$$

Because p_L is decreasing in q, $p_L(p_0, q)$ is higher than p* only when q is relatively low.[19] Therefore, when q is relatively low, s may trigger an *inefficient* run, so depositors are more eager to withdraw when they learn that s will be revealed. In contrast, when q is relatively high (so that $p_L(p_0, q) < p^*$), s can trigger an *efficient* bank run, so depositors are more willing to wait until subdate 1.2 when they learn that s will be revealed.

The precision of the signal also determines the type of panic runs that will occur. When s is relatively noisy (so $p_N < p_M(q)$) and $p_N < p_0 < p_M(q)$, nothing happens at subdate 1.1 if s will not be revealed (since $p_0 > p_N$) and a panic run occurs if s will be revealed (since $p_0 < p_M(q)$). On the other hand, when s is relatively precise (so $p_M(q) < p_N$) and $p_M(q) < p_0 < p_N$, nothing happens at subdate 1.1 if s will be revealed (since $p_0 > p_M(q)$), and a panic run occurs if s will not be revealed (since $p_0 < p_N$).[20]

The case where $p_N < p_0 < p_M(q)$ has an interesting implication. Given $p_0 > p_N$, the bank is sound in the sense that no bank run will occur if no new information will be revealed. However, as mentioned, a panic run will occur in this case if depositors learn that s will be revealed. The result that a panic run can occur at a sound bank provides an explanation for why all banks rather than only the

[19] Note that equation (3.6) excludes the possibility that $p_L(p_0, q) \geq p_N$.

[20] Note that (3.12) implies $p_0 > \min\{p_N, p_M(q)\}$. If $p_0 \leq \min\{p_N, p_M(q)\}$, by Proposition 1 a depositor's expected payoff for making deposits is no larger than r, which violates (3.12).

financially weak ones suffer massive withdrawals during large scale banking panic.

A policy implication that follows from this analysis is that suspension of convertibility can alleviate the panic run problem. Depositor welfare may be higher if the bank suspends convertibility at subdate 1.1 and allows depositors to withdraw only at subdate 1.2.

Proposition 3. If $p_N < p_0 < p_M(q)$, then allowing the bank to suspend convertibility at subdate 1.1 *strictly* improves depositor welfare.

Proof. See Appendix.

Proposition 3 states a condition under which suspension of convertibility strictly improves depositor welfare. Suppose $p_N < p_0 < p_M(q)$ and depositors learn that s will be revealed. In this case, a panic run always occurs at subdate 1.1 if there is no suspension of convertibility. By contrast, if convertibility is suspended at subdate 1.1, a bank run will occur at subdate 1.2 only when $s = L$. By forcing depositors to delay withdrawing decisions until s is revealed, suspension of payments reduces the probability of a bank run. Since the bank run equilibrium is always Pareto dominated, reducing the probability of a bank run is welfare improving. This result is consistent with the observation of Dwyer and Hasan (2006) that suspension of payments reduces the probability of a bank closure by twenty five percent.

Two caveats of the model are worth mentioning. First, the assumption about the bank's return is critical to our results. A necessary condition for Proposition 2 to hold is that information-based bank runs are welfare improving when bank-specific information is relatively precise. Under the assumption that the bank's return is either R or 0, the bank's conditional return given s is either very large (close to R) or very small (close to 0) as the signal becomes precise, so an information-based run is always welfare improving when s is relatively precise. If the bank's return is continuously distributed, an information-based bank run may still be welfare decreasing even if the signal is perfect.[21] It may seem then, that our main result (Proposition 2) is not robust. However, we do not consider this as a serious problem since our simple assumption about the bank return captures the feature that information-based bank runs can play a positive role in disciplining banks when bank-specific information is precise. We conjecture that, even if some

[21] To see this, suppose that the return on the bank's project is continuously distributed, and depositors perfectly learn the realized return at date 1. Let y denote the realized return. Assume that a bank run is welfare improving if and only if $y < y^*$, and that a bank run will occur if and only if $y < y_N$. Since depositors still have excessive incentives to withdraw in our model, we know that $y^* < y_N$. Therefore, an inefficient bank run occurs when $y^* < y < y_N$.

assumptions of the model are changed, our results will hold as long as this feature is preserved.

The second caveat is that, when discussing suspension of payments, we do not consider other costs that may be incurred. In particular, when a bank's payments are suspended, depositors who need liquidity urgently will suffer losses. When these costs are considered, suspension of convertibility can be justified only when the benefits are large enough to outweigh the costs.[22]

4 Concluding remarks

This paper shows that the depositors' expectations about the quality and amount of bank-related information that will be revealed can affect their incentives to withdraw. It provides an explanation for why bank runs may look like panic, and generates results that are consistent with the empirical evidence about bank runs. Extending the model to investigate how bank regulations such as capital requirements and deposit insurance affect the panic run problem is left for future research.

[22] Calomiris (1990) suggests that suspension of convertibility did not cause substantial welfare losses.

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Appendix

Proof of Proposition 2

For part (a) of the proposition, since V_M is increasing in p_0, $p_M(q) > p_N$ if and only if $V_M(p_N, q) < r = V_{NW}(p_N)$. By (3.7) and the fact that

$$V_{NW}(p_N) = \pi_H V_{NW}(p_H(p_N, q)) + \pi_L V_{NW}(p_L(p_N, q))$$

$V_M(p_N, q) < V_{NW}(p_N)$ if and only if $V_{BR} < V_{NW}(p_L(p_N, q))$, or equivalently

$$p_L(p_N, q) = \frac{p_N (1-q)}{p_N (1-q) + (1-p_N)\, q} > p^*$$

Note that p_L is decreasing in q and p* is independent of q. Moreover, $p_L(p_N, 0.5) = p_N$ and $p_L(p_N, 1) = 0$. Therefore, there exists a $q_C \in (0.5, 1)$ such that $p_L(p_N, q) > p^*$ if and only if $q < q_C$. This completes the proof of part (a). For part (b), note that (3.12) implies $p_0 > \min\{p_N, p_M(q)\}$. If $q < q_C$, a panic run will occur if and only if $p_N < p_0 < p_M(q)$ and s will be revealed. If $q > q_C$, a panic run will occur if and only if $p_M(q) < p_0 < p_N$ and s will not be revealed. This completes the proof of the proposition. **Q.E.D.**

Proof of Proposition 3.

When $p_N < p_0 < p_M(q)$, the depositors' payoff at date 0 is $\alpha V_{BR} + (1-\alpha)V_{NW}(p_0)$ when there is no suspension of convertibility, and is $\alpha V_M(p_0, q) + (1-\alpha) V_{NW}(p_0)$ when there is. Therefore, suspension of convertibility raises depositor welfare if and only if $V_M(p_0, q) > V_{BR}$, or equivalently, $V_{NW}(p_H(p_0, q)) > V_{BR}$. By (3.3) and (3.6), we know that $V_{NW}(p_H(p_0, q)) > r > V_{BR}$. This completes the proof of the proposition. **Q.E.D.**

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