

Contents lists available at [ScienceDirect](#)

European Economic Review

journal homepage: www.elsevier.com/locate/eev

Bailouts and bank runs: Theory and evidence from TARP

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ARTICLE INFO

Article history:

Received 15 January 2013

Accepted 17 August 2013

Available online 7 September 2013

JEL classification:

E5

G01

G28

Keywords:

Bailout

Bank run

ABSTRACT

During the recent financial crisis, there were bank runs right after government bailout announcements. This paper develops a global game model of information based bank runs to analyze how the announcement of bailouts affects investors' bank run incentives. The equilibrium probability of bank runs is uniquely determined. I conclude that before the announcement, the existence of such bailout policy reduces investors' bank run incentives, but after the announcement, investors may run on the bank, since such an announcement reflects the government's information about the bad bank asset. The empirical evidence from TARP is consistent with my theory.

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1. Introduction

Bank runs and government bailouts became more prevalent during the 2007–2009 financial crisis. In the years of 2008 and 2009, 165 banks failed in the US, in which bank runs are a notable cause. However, only 11 banks failed in the five years before 2008. Even for large financial institutions, there were runs on Northern Rock, Bear Stearns, IndyMac Bank, Washington Mutual, and AIG. The government interventions in the form of various bailouts in the banking sector during this crisis were also the largest in US history. Even though the stated goal of these interventions is to “restore confidence to our financial system”,¹ several bank runs happened right after their bailout announcements.

In his description of bank runs during the 2007–2009 crisis, [Brunnermeier \(2009\)](#) wrote

“...[on] March 11 [2008], ...the Federal Reserve announced its \$200 billion Term Securities Lending Facility. This program allowed investment banks to swap agency and other mortgage-related bonds for Treasury bonds for up to 28 days.... Naturally, they (market participants) pointed to the smallest, most leveraged investment bank with large mortgage exposure: Bear Stearns.....Bear's liquidity situation worsened dramatically the next day as it was suddenly unable to secure funding on the repo market.”

For the case of Northern Rock, [Shin \(2009\)](#) wrote “On September 13, 2007, the BBC's evening television news broadcast first broke the news that Northern Rock had sought the Bank of England's support. The next morning, the Bank of England announced that it would provide emergency liquidity support. It was only after that announcement—that is, after the central bank had announced its intervention to support the bank—that retail depositors started queuing outside the branch offices.”

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¹ Statement by Secretary Henry M. Paulson, Jr. on Actions to Protect the U.S. Economy, October 14, 2008. <http://www.huntonfinancialindustry.com/sourcecenter/uploads/file/Paulson%20statement.pdf>.

The above facts contradict the stated goal of government interventions to “restore confidence”. For these cases, bailouts did not prevent but triggered bank runs. In this paper, I will analyze the effect of bailout announcements on the probability of bank runs.

I consider the following environment. Investors put their funds in a bank. The bank invests these funds in an asset. The quality of a bank's asset is random. Investors choose whether to withdraw their investments early or to wait until the asset is mature. The liquidation of the investment is costly. The government and investors receive private noisy signals of the quality of the bank's asset after its realization. Government bails out a bank in the form of capital injection only if its signal is below some cutoff threshold, i.e., the government helps a bank that is in trouble.

With the model environment above, the announcement of bailouts may increase the probability of bank runs. I use the word “may” because there are two effects. The first one is the capital injection effect in the sense that money transfer to a bank reduces the probability of bank runs. The second is the signaling effect, i.e., the announcement signals the government's information that the bank's asset quality is low, which increases the probability of bank runs. The total effect depends on the magnitude of the two separate effects. The model implies that the probability of bank runs after bailout announcements depends on three factors. First, the probability of a bank run is higher if the bailout amount is smaller. The government providing any positive bailout amount has a constant information effect no matter what the bailout amount is. But the capital injection effect is stronger for a larger bailout. Second, the probability of a bank run is higher if the government signal is more precise. Once a bailout is announced, for the government with a more precise signal, investors will believe it is more likely that the bank fundamental is below the bailout cutoff. Third, the probability of a bank run is higher when the government uses a lower cutoff. Conditional on a bailout, investors deduce from a lower cutoff that the government believes the bank is worse.

The model also provides insights from an ex ante perspective. I consider two economies. The government in economy A commits never to bail out any banks. The government in economy B uses the above assumed exogenous strategy to bail out banks. The probability of bank runs may increase after the announcement of bailouts. However, ex ante, i.e., before the announcement of bailouts, the probability of bank runs in economy B is lower than the probability of bank runs in economy A, because the capital injection effect dominates in economy B. Signaling does not impact the investors' bank run incentives since the government has not announced yet whether the bank will be bailed out or not.

I provide suggestive evidence by studying government bailouts and bank runs during the 2008–2009 financial crisis. The bailouts are from the \$700 billion TARP. I use two methods to measure the probability of bank runs, which complement each other with their distinctive advantages. I find evidence consistent with my previous arguments.

In the classic bank run work by [Diamond and Dybvig \(1983\)](#), there are multiple equilibria due to coordination failure, which cause policy analysis infeasible. [Goldstein and Pauzner \(2005\)](#) apply the global game technique to the classic Diamond–Dybvig framework to obtain a unique equilibrium. I add a government sector to their unique equilibrium framework to examine how government bailout announcements affect a bank's risk of experiencing runs. Global games with signaling in a currency crisis context have also been analyzed by [Angeletos et al. \(2006\)](#). Different from my unique equilibrium result, their work has an unappealing multiple equilibria feature by considering the feedback effect from investors' behavior to that of the policy maker. The work by [Keister \(2010\)](#) is closest in theme with mine in studying bailouts and bank runs, but focuses on the time inconsistency government problem. He concludes that it is optimal for the government to bail out banks when a crisis occurs by reducing the public good consumption. In contrast to his paper's focus on optimal policy and moral hazard by assuming bank runs as sunspots, my paper mainly pays attention to the endogeneity of probability of bank runs and to how policy affects that probability.

The rest of the paper proceeds as follows. The benchmark model is introduced in [Section 2](#). A full model with an exogenous government bailout policy is presented in [Section 3](#). [Section 4](#) provides empirical evidence for the theoretical arguments. [Section 5](#) concludes.

2. Benchmark model without information dispersion

The benchmark model without information dispersion is a variation of the Diamond–Dybvig economy ([Diamond and Dybvig, 1983](#)).

2.1. The economy

There are three periods, $t=0,1,2$, one homogeneous good, and a continuum $[0, 1]$ of investors. Each investor has an endowment of one unit. They enter the economy in period 0, and consumption happens in either period 1 or 2, denoted by c_1 and c_2 . The timing for consumption depends on their types. Investors do not know their types until period 1. There are two types of investors, patient and impatient. The fraction of impatient investors is λ . So the probability for an investor to become patient investors in period 1 is $1-\lambda$. The utility functions for patient and impatient investors are $u(c_1 + c_2)$ and $u(c_1)$, respectively. The utility function, which is twice continuously differentiable and increasing, satisfies $u(0) = 0$ and relative risk aversion coefficient, $-cu''(c)/u'(c) > 1$ for any $c \geq 1$.

Investors can place their endowments in period 0 in an asset which in period 2 yields R with probability θ , or 0 with probability $1-\theta$, where $R > 1$, and θ , the underlying fundamental of the asset, which determines the expected asset return,

is distributed uniformly on $[0, 1]$. I assume $E_\theta[u(R)] > u(1)$ so that the expected long term return is higher than the short term return. If the asset is liquidated in period 1, it will yield just one unit for any one unit of input.

2.2. Banks and contract

Banks are financial intermediaries which put investors' endowments in the asset mentioned above. Banks issue demand deposit contract as illustrated in Diamond and Dybvig (1983). The contract is specified as follows. Each investor deposits her endowment in period 0. If she demands withdrawal in period 1, she is promised a fixed payment, $r > 1$. Sequential service constraint is satisfied, i.e., a bank pays r to investors until it runs out of resources. If she waits to withdraw in period 2 after the asset matures, she is paid with the leftovers divided by the share of investors who remain (withdraw in period 2). So the payment in period 2 will be stochastic.

s is an indicator to denote the strategies of the investors in period 1. Actions for patient investors

$$s = \begin{cases} 1 & \text{if "withdraw"} \\ 0 & \text{if "wait"} \end{cases}$$

For impatient investors, their action is always to withdraw, since they only care about the first period consumption.

The payment to the investors in period 2, \tilde{r} , is depicted in Table 1, where n is the share of investors who demand early withdrawal in period 1. As demonstrated by Diamond and Dybvig (1983), there are two equilibria in this model. One is “no bank run” equilibrium where $n = \lambda$; $s = 0$. The other one is “bank run” equilibrium where $n = 1$; $s = 1$. Bank runs are driven by coordination motives. The optimal action for an investor is to run if others run, and the optimal action for an investor is to wait if others wait. The model with such multiple equilibria feature is unsuitable for policy analysis, since it is impossible to address the effect of bailouts on the probability of bank runs. To achieve a unique equilibrium, I utilize the global game technique by adding information dispersion to the model.

3. Model with information dispersion and government bailout

3.1. The Economy

3.1.1. Timing

Fig. 1 shows the timing of the model.

3.1.2. Information

The state of the economy, θ , is realized at the beginning of period 1. Investors cannot observe θ , but for every i , investor i receives a noisy signal about θ , $\theta_i = \theta + \varepsilon_i$, where ε_i is distributed uniformly over $[-\bar{\varepsilon}, \bar{\varepsilon}]$. The distribution of the signal is public knowledge.

Table 1
Ex post payments to investors.

Period	$n < \frac{1}{r}$	$n \geq \frac{1}{r}$
1	$\tilde{r} = r$	$\tilde{r} = \begin{cases} r \text{ w. prob } \frac{1}{nr} \\ 0 \text{ w. prob } 1 - \frac{1}{nr} \end{cases}$
2	$\tilde{r} = \begin{cases} \frac{1-nr}{1-n}R \text{ w. prob } \theta \\ 0 \text{ w. prob } 1-\theta \end{cases}$	$\tilde{r} = 0$

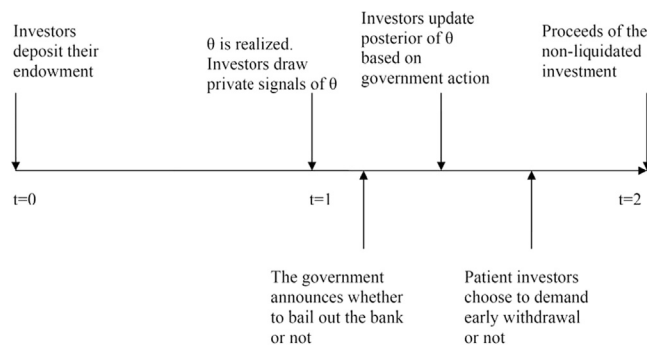


Fig. 1. Timing.

3.1.3. Government

The government tries to help banks which are in trouble, i.e., banks with a low fundamental. Due to its limited auditing ability, the government does not have perfect information about the bank fundamental. It obtains a noisy signal about the fundamental, $\theta_G = \theta + \eta$, where η is distributed uniformly over $[-\bar{\eta}, \bar{\eta}]$. In period 1, once the government observes the bank's fundamental is so low that the bank is vulnerable to runs, the government will inject \bar{B} amount of liquidity to the bank. So the government's strategy takes the following form:

$$\tilde{B} = \begin{cases} \bar{B} & \text{if } \theta_G < \theta_G^* \\ 0 & \text{if } \theta_G \geq \theta_G^* \end{cases} \quad (1)$$

where \tilde{B} is a random variable which takes value \bar{B} if government's perception about the bank fundamental is sufficiently low, below some exogenous cutoff threshold θ_G^* . Otherwise, $\tilde{B} = 0$, i.e., the government just leaves the bank untouched. Investors know the above strategy including the value of θ_G^* , but cannot directly observe θ_G . I use B to denote the event that $\theta_G < \theta_G^*$, and N to denote the event that $\theta_G \geq \theta_G^*$. For a real-life example, the U.S. supervisory regulators use the CAMELS ratings to evaluate a bank's overall condition, where the acronym CAMELS refers to Capital adequacy, Asset quality, Management, Earnings, Liquidity, and Sensitivity to market risk. The ratings are not released to the public to prevent a possible bank run on downgraded institutions.²

Under this assumption, conditional on a government bailout announcement, Table 2, which is symmetric to Table 1, depicts the ex post payment to the patient investors.

For a given state θ , the incentive for patient investors to withdraw in period 2, which is the payoff in period 2 if waiting minus the payoff in period 1 if running, is

$$v(\theta, n, \tilde{B}) = \begin{cases} \theta u\left(\frac{1+\tilde{B}-nr}{1-n}R\right) - u(r) & \text{if } \frac{1+\tilde{B}}{r} \geq n \geq \lambda \\ 0 - \frac{1+\tilde{B}}{nr}u(r) & \text{if } 1 \geq n \geq \frac{1+\tilde{B}}{r} \end{cases} \quad (2)$$

where the first element under each condition is the payoff in period 2 if waiting and the second is the payoff in period 1 if withdrawing early. v decreases with n , only when $n \leq (1+\tilde{B})/r$, as drawn in Fig. 2.

3.2. Equilibrium

First, I describe the information structure by showing the posterior distribution of investor i 's information about bank fundamental θ conditional on the event of a bailout announcement and investor i 's private information θ_i . For investor i , conditional on obtaining the signal θ_i , her posterior about θ is

$$\theta \sim U[\max(\theta_i - \bar{\varepsilon}, 0), \min(\theta_i + \bar{\varepsilon}, 1)]$$

Conditional on the event that $\theta_G < \theta_G^*$, investors' posterior is

$$\theta \sim U[0, \min(\theta_G^* + \bar{\eta}, 1)]$$

Lemma 1. For investor i who observes a bailout and obtains signal θ_i , the support of the conditional distribution from $\theta|\theta_i$ and $\theta|B$ overlaps with each other. The posterior is

$$\theta|\theta_i, B \sim U[\max(0, \theta_i - \bar{\varepsilon}), \min(1, \theta_G^* + \bar{\eta}, \theta_i + \bar{\varepsilon})] \quad (3)$$

In the same way, the posterior for an investor who observes θ_i and conditional on no bailout announcement is

$$\theta|\theta_i, N \sim U[\max(0, \theta_G^* - \bar{\eta}, \theta_i - \bar{\varepsilon}), \min(1, \theta_i + \bar{\varepsilon})]. \quad (4)$$

Proof. Please refer to Appendix A. \square

Before I turn to define the equilibrium, some illustrations are necessary. Conditional on a bailout announcement, a (mixed) strategy for investor i is a measurable function $s_i : ([0 - \bar{\varepsilon}, 1 + \bar{\varepsilon}], B) \rightarrow [0, 1]$ which indicates the probability that patient investor i demands early withdrawal given her signal θ_i , and a bailout announcement B , where $s_i(\theta_i, B) = 1$ indicates withdrawing and $s_i(\theta_i, B) = 0$ indicates waiting. Let $\Delta(\theta_i; n(\cdot, B), B)$ denote the expected value of the utility differential $v(\theta; n(\theta, B), B)$, as shown in (2) when $\tilde{B} = \bar{B}$, for investor i between waiting and withdrawing in period 1, where $n(\cdot, B)$ denotes investor's belief regarding the proportion of investors who run at each state θ . The expressions are

$$n(\theta, B) = \lambda + \frac{(1-\lambda)}{2\bar{\varepsilon}} \int_{-\bar{\varepsilon}}^{\bar{\varepsilon}} s_i(\theta + \varepsilon_i, B) d\varepsilon_i$$

² For details, please see <http://www.frbsf.org/econsrch/wklyltr/wklyltr99/el99-19.html>.

Table 2
Ex post payments to investors.

Period	$n < \frac{(1+\bar{B})}{r}$	$n \geq \frac{(1+\bar{B})}{r}$
1	r	$\begin{cases} r \text{ with prob } \frac{1+\bar{B}}{nr} \\ 0 \text{ with prob } 1 - \frac{1+\bar{B}}{nr} \end{cases}$
2	$\tilde{r} = \begin{cases} \frac{1+\bar{B}-nr}{1-n}R \text{ with prob } \theta \\ 0 \text{ with prob } 1-\theta \end{cases}$	$\tilde{r} = 0$

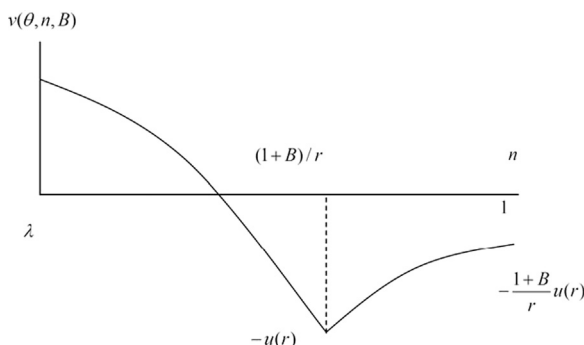


Fig. 2. The net incentive to wait.

$$\Delta(\theta_i; n(\cdot, B), B) = \frac{1}{\min(1, \theta_G^* + \bar{\eta}, \theta_i + \bar{\varepsilon}) - \max(0, \theta_i - \bar{\varepsilon})} \int_{\max(0, \theta_i - \bar{\varepsilon})}^{\min(1, \theta_G^* + \bar{\eta}, \theta_i + \bar{\varepsilon})} v(\theta; n(\theta, B), B) d\theta \tag{5}$$

Conditional on no bailout announcement, a (mixed) strategy for investor i is a measurable function $s_i : ([0 - \bar{\varepsilon}, 1 + \bar{\varepsilon}], N) \rightarrow [0, 1]$ which indicates the probability that patient investor i demands early withdrawal given her signal θ_i , and no bailout announcement N , where $s_i(\theta_i, N) = 1$ indicates withdrawing and $s_i(\theta_i, N) = 0$ indicates waiting. Let $\Delta(\theta_i; n(\cdot, N), N)$ denote the expected value of the utility differential $v(\theta; n(\theta, N), N)$, as shown in (2) when $\bar{B} = 0$, for investor i between waiting and withdrawing in period 1; $n(\cdot, N)$ denotes investor's belief regarding the proportion of investors who run at each state θ ,

$$n(\theta, N) = \lambda + \frac{(1-\lambda)}{2\bar{\varepsilon}} \int_{-\bar{\varepsilon}}^{\bar{\varepsilon}} s_i(\theta + \varepsilon_i, N) d\varepsilon_i$$

$$\Delta(\theta_i; n(\cdot, N), N) = \frac{1}{\min(1, \theta_i + \bar{\varepsilon}) - \max(0, \theta_G^* - \bar{\eta}, \theta_i - \bar{\varepsilon})} \int_{\max(0, \theta_G^* - \bar{\eta}, \theta_i - \bar{\varepsilon})}^{\min(1, \theta_i + \bar{\varepsilon})} v(\theta; n(\theta, N), N) d\theta \tag{6}$$

If all patient investors have the same threshold strategy, I use $n(\theta, \theta')$ to denote $n(\theta)$, where θ' is the common threshold.

Definition 1. A Bayesian equilibrium is a measurable strategy profile $\{s_i(\theta_i, B), s_i(\theta_i, N)\}_{i \in [0,1]}$, such that each patient investor chooses the best action at each signal, given the strategies of the other investors. Specifically, in equilibrium

- (1) Conditional on the event of bailout B , patient investor i who receives signal θ_i chooses to run on the bank $s_i(\theta_i, B) = 1$, if his expected utility of running on the bank is larger than waiting, i.e., $\Delta(\theta_i; n(\cdot, B), B) < 0$. In the same way, $s_i(\theta_i, B) = 0$ if $\Delta(\theta_i; n(\cdot, B), B) > 0$; $0 \leq s_i(\theta_i, B) \leq 1$ if $\Delta(\theta_i; n(\cdot, B), B) = 0$;
- (2) Conditional on the event of no bailout N , patient investor i who receives signal θ_i chooses to run on the bank $s_i(\theta_i, N) = 1$, if his expected utility of running on the bank is larger than waiting, i.e., $\Delta(\theta_i; n(\cdot, N), N) < 0$; In the same way, $s_i(\theta_i, N) = 0$ if $\Delta(\theta_i; n(\cdot, N), N) > 0$; $0 \leq s_i(\theta_i, N) \leq 1$ if $\Delta(\theta_i; n(\cdot, N), N) = 0$.

Based on this definition, the following proposition can be obtained.

Proposition 1. Conditional on the event B , the model has a unique threshold equilibrium in which patient investors who observe signals below threshold θ_B^* choose to run, $s_i(\theta_i, B) = 1$, and do not run above, $s_i(\theta_i, B) = 0$, and conditional on the event N , the

model has a unique threshold equilibrium in which patient investors who observe signals below threshold θ_N^* choose to run, $s_i(\theta_i, N) = 1$, and do not run above, $s_i(\theta_i, N) = 0$.

Proof. Please refer to Appendix A.³ □

Below I sketch the proof and provide intuition for the case when there is a bailout announcement, i.e., $\tilde{B} = \bar{B}$. The proof for the case when $\tilde{B} = 0$ is omitted since it is just the symmetry of the former. Before advancing to the main part of the proof, I need to characterize the lower dominance region which is essential for the main proof. But first of all, I need to define *bank runs*.

Definition 2 (Bank run). I define a bank run as the share of investors who demand early withdrawals in period 1 is larger than the maximum share of investors the bank can serve, i.e.,

$$n = \lambda + (1 - \lambda)\psi \geq \frac{1 + \bar{B}}{r}$$

where ψ denotes the share of patient investors who demand early withdrawals.

In this paper, I restrict parameter λ to satisfy

$$\lambda + \frac{1 - \lambda}{2} = \frac{1 + \bar{B}}{r}$$

so that, as long as the fraction of patient investors who demand early withdrawal is larger than $\frac{1}{2}$, then I call there is a bank run.⁴

Since I restrict attention to threshold equilibrium, it means that the share of investors who will run on the bank is

$$n(\theta) = \lambda + (1 - \lambda) \frac{\theta_B^* - (\theta - \bar{e})}{2\bar{e}} \tag{7}$$

when the cutoff threshold is θ_B^* .

When the fundamental is very bad, patient investors run independently of other investors' action. I refer to this region as the lower dominance region. Even if all the other patient investors choose to wait, she still runs. I set $n = \lambda$, and use $\underline{\theta}(r, \bar{B})$ to denote the bank fundamental which makes investors indifferent

$$u(r) = \underline{\theta} u \left(\frac{1 + \bar{B} - \lambda r}{1 - \lambda} R \right)$$

$$\underline{\theta}(r, \bar{B}) = \frac{u(r)}{u \left(\frac{1 + \bar{B} - \lambda r}{1 - \lambda} R \right)}$$

Investor i demands early withdrawal if $\theta_i < \underline{\theta}(r, \bar{B}) - \bar{e}$.

In this paper, I only focus on threshold equilibria. There are two steps for the rest of the proof. First, I derive the basic properties of the *run function*, $\Delta(\theta_i; n(\cdot, B), B)$, defined as the expected utility differential between waiting and withdrawing. Second, I establish that there exists a unique threshold equilibrium.

Step1: For a given state θ , the incentive to withdraw in period 2, which is the payoff if waiting minus the payoff in period 1 if running, is

$$v(\theta, n, \bar{B}) = \begin{cases} \theta u \left(\frac{1 + \bar{B} - nr}{1 - n} R \right) - u(r) & \text{if } \frac{1 + \bar{B}}{r} \geq n \geq \lambda \\ 0 - \frac{1 + \bar{B}}{nr} u(r) & \text{if } 1 \geq n \geq \frac{1 + \bar{B}}{r} \end{cases} \tag{8}$$

v decreases with n , only when $n \leq (1 + \bar{B})/r$, as drawn in Fig. 2.

The expected utility differential for investor i is

$$\Delta(\theta_i; n(\cdot, B), B) = \frac{1}{\min(1, \theta_G^* + \bar{\eta}, \theta_i + \bar{e}) - \max(0, \theta_i - \bar{e})} \int_{\max(0, \theta_i - \bar{e})}^{\min(1, \theta_G^* + \bar{\eta}, \theta_i + \bar{e})} v(\theta; n(\cdot, B), B) d\theta \tag{9}$$

In Appendix A, I show that the function $\Delta(\theta_i; n(\cdot, B), B)$ is continuously increasing in θ_i and it's strictly increasing if $n(\theta) \leq (1 + \bar{B})/r$.

³ All the appendices can be found online as supplementary materials.

⁴ The following analysis will go through for any other value of λ .

Step 2: To prove that there exists a unique threshold equilibrium, I only need to prove that given that all other patient investors use threshold strategy θ_B^* , patient investor i runs if and only if $\theta_i < \theta_B^*$, and waits if and only if $\theta_i > \theta_B^*$, i.e.,

$$s_i = 1 \text{ if } \Delta(\theta_i, n(\cdot, \theta_B^*), \bar{B}) < 0 \quad \forall \theta_i < \theta_B^* \tag{10}$$

$$s_i = 0 \text{ if } \Delta(\theta_i, n(\cdot, \theta_B^*), \bar{B}) > 0 \quad \forall \theta_i > \theta_B^* \tag{11}$$

$$\Delta(\theta_i, n(\cdot, \theta_B^*), \bar{B}) = 0 \quad \forall \theta_i = \theta_B^*$$

Appendix A shows that there is exactly one value of θ_B^* that satisfies $\Delta(\theta_B^*, n(\cdot, \theta_B^*), \bar{B}) = 0$, which follows from the existence of the lower dominance region, and that $\Delta(\theta_B^*, n(\cdot, \theta_B^*), \bar{B})$ is continuously increasing in θ_B^* and it is strictly increasing if $n(\theta) \leq (1 + \bar{B})/r$, which can be directly derived from Lemmas 2 and 3 in Appendix A. Then, in Appendix A, I show that given $\Delta(\theta_B^*, n(\cdot, \theta_B^*), \bar{B}) = 0$, (10) and (11) can be obtained by using the single crossing property of $\Delta(\theta_i, n(\cdot, \theta_B^*), \bar{B})$.

Proposition 1 states that there exists a unique threshold equilibrium which determines the probability of bank runs. I now do some comparative statics to illustrate how various factors can influence the probability of bank runs.

Proposition 2. Conditional on the event B , the probability of bank runs, $\Pr(\theta \leq \theta_B^* | \bar{B} = \bar{B})$, which is proportional to $\theta_B^*(\bar{B}, \theta_G^*, \bar{\eta})$, is a decreasing function of the bailout level \bar{B} , the government strategy cutoff θ_G^* , and the precision of government signal $\bar{\eta}$,

$$\frac{\partial \theta_B^*(r, \bar{B}, \theta_G^*, \bar{\eta})}{\partial \bar{B}}, \quad \frac{\partial \theta_B^*(r, \bar{B}, \theta_G^*, \bar{\eta})}{\partial \theta_G^*}, \quad \frac{\partial \theta_B^*(r, \bar{B}, \theta_G^*, \bar{\eta})}{\partial \bar{\eta}} \leq 0.$$

Proof. Please refer to Appendix B. □

Proposition 2 provides three insights for bank runs after a bailout announcement. For θ_G^* , it states that the probability of bank runs, defined as the proportion of investors who demand early withdrawal, i.e., those who obtain signals below θ_B^* , becomes higher as the government uses a smaller cutoff θ_G^* to bail out the bank.

For \bar{B} , if I increase the value of \bar{B} while keeping other variables on the right hand side constant, θ_B^* is lower, i.e., the probability of a bank run decreases. While keeping the information effect θ_G^* constant, injecting more capital to a bank will reduce the probability of a bank run. Therefore, there are two opposite effects of a bailout announcement on the probability of bank runs. For $\bar{\eta}$, a higher government signal precision, i.e., a lower $\bar{\eta}$, will lead to a higher probability of bank runs. The reason is that a higher signal precision will make the investors be more sure that the bank fundamental is below θ_B^* .

This paper is motivated by the argument in the Introduction section that a bailout announcement may increase the probability of bank runs. The following corollary, which is a comparison of θ_N^* and θ_B^* , is such an exposition which follows directly from Proposition 2.

Corollary 1. There exist \hat{B} , $\hat{\theta}_G^*$, $\hat{\eta}$, such that

$$\text{Conditional on } \theta_G^* \quad \text{and } \bar{\eta}, \theta_B^* \leq \theta_N^* \quad \text{for } \bar{B} \leq \hat{B}; \theta_B^* > \theta_N^* \quad \text{for } \bar{B} > \hat{B}$$

$$\text{Conditional on } \theta_G^* \quad \text{and } \bar{B}, \theta_B^* \leq \theta_N^* \quad \text{for } \bar{\eta} \leq \hat{\eta}; \theta_B^* > \theta_N^* \quad \text{for } \bar{\eta} > \hat{\eta}$$

$$\text{Conditional on } \bar{B} \quad \text{and } \bar{\eta}, \theta_B^* \leq \theta_N^* \quad \text{for } \theta_G^* \leq \hat{\theta}_G^*; \theta_B^* > \theta_N^* \quad \text{for } \theta_G^* > \hat{\theta}_G^*.$$

Proof. Please refer to Appendix B. □

Corollary 1 states that under the specific conditions, a bailout announcement increases the probability of bank runs. After analysis of the equilibrium and subsequent comparative statics, I now turn to the ex ante case by comparing economies with and without bailouts.

3.3. Comparing economies with and without bailouts (ex ante)

To examine the efficiency of government bailout commitment in ensuring financial stability by reducing the probability of bank runs, I need to compare the probability of bank runs in an economy where the government executes the cutoff strategy as specified in (1) and the probability in another economy where the government commits never to bail out the bank.

Proposition 3. Assume $r = 1$.⁵ For $\bar{B} > 0$, the probability of a bank run in the economy where the government commits never to bail out a bank, $\Pr(\theta < \theta^*)$, is higher than the probability of bank runs in the economy where the government uses the above bailout strategy, i.e.,

$$\Pr(\theta < \theta^*) > \Pr(\theta < \theta_B^* | \theta_G < \theta_G^*) \Pr(\theta_G < \theta_G^*) + \Pr(\theta < \theta_N^* | \theta_G \geq \theta_G^*) \Pr(\theta_G \geq \theta_G^*)$$

⁵ I use this assumption for the simplicity of the calculation of θ_B^* . Under this assumption, all the runs are information based.

where θ^* is the unique equilibrium cutoff threshold for an economy where the government commits never to bail out a bank; both θ_B^* and θ_N^* are equilibrium threshold cutoffs in the economy where the government uses the above bailout strategy; θ_B^* is the unique equilibrium cutoff threshold after a bailout announcement; θ_N^* is the unique equilibrium cutoff threshold after no bailout announcement.

Proof. Please refer to Appendix B. \square

This proposition states that in the economy where government commits never to bail out any bank, the ex ante probability of bank runs is higher than that in the economy with government bailouts. In the latter economy, there are two ex post effects conditional on bailout or no bailout, i.e., information effect and capital injection effect. Conditional on bailout, the signaling information effect increases the probability of bank runs but capital injection effect decreases the probability of bank runs. In the latter economy, the no bailout announcement will boost investors' confidence by assuring investors that the bank does not need government help due to its soundness. The overall probability of bank runs is lower than that in the economy where government commits the no bailout policy.

4. Empirical evidence from the 2008–2009 financial crisis

In this section, I provide suggestive evidence to support the arguments from the theoretical model by investigating TARP in the US. Two main conclusions from the theoretical model are (1) a bank bailout announcement may increase the probability of bank runs, which is from Proposition 2 and Corollary 1; (2) before banks' specified bailout announcements, the existence of the above mentioned bailout policy reduces the probability of bank runs, compared to the government policy which rules out bailouts, which is from Proposition 3. I then explain how these two conclusions are tested.

The announcement of TARP is composed of two parts. The first part is recipient unspecified bailout announcements. The 700 billion dollar Paulson plan was in the news on September 20th, 2008, or more formally appeared on September 22nd.⁶ This bailout proposal was passed by the Congress on October 3rd, 2008.⁷ In this plan, the government announced the banking sector would be bailed out, but did not specify the names of banks who would receive bailouts except the ten largest banks. October 3rd can be viewed as an announcement of the existence of an ex ante bailout policy, since bank names were not disclosed, which will be used to test the first main conclusion. The first theoretical conclusion implies that the recipient unspecified bailout announcement on October 3rd will generate a positive mean abnormal return.

The second part of bailout announcements is periodically specified announcements which contain more details, including banks' names and their bailout amounts. There are 241 banks with their stock price returns available in my dataset that received bailouts. One thing to be noted is that investors expected that the bailouts were mainly for the large banks on Wall Street.⁸ I thus use the date, October 3, 2008 as the exact date of bailout announcements for the top 10 banks. The first measure of bank runs, the bank run index constructed by Veronesi and Zingales (2010), is more precise, but is limited to eight banks due to the availability of Credit Default Swap (CDS) rates, which are used to construct the index. A higher bank run index indicates a higher probability of bank runs. I find that, for some banks, their bank run indices increased dramatically after their individual bailout announcements. The second approach provides suggestive evidence by utilizing the stock price abnormal returns in response to bailout announcements to measure the probability of bank runs, which can be applied to 241 banks. The higher the abnormal return, the lower the probability of bank runs. The theoretical justification for using this approach is as follows. The debt investor's payoff resembles that of the equity holder, in the sense that the payoffs of both the debt and equity holder depend on the asset return. The classic bank runs or debt runs can be extended to the equity holders, such as investors in hedge funds or mutual funds (Shleifer and Vishny, 1997; Brunnermeier, 2009). If I add equity holders in my model, I would obtain the result that the probability of a bank run increases as the abnormal return goes down. For the original Paulson plan which was proposed on September 20, 2008 and passed on October 3, 2008, the mean stock price abnormal return for banks in my dataset was positive using various cumulative intervals. Since the names of these banks were not known until their own specific bank bailouts later on, I find this confirms my ex ante argument, i.e., the existence of bailouts reduces the probability of bank runs. Consistent with my first theoretical conclusion, after banks' own individual bailout announcements, they displayed significant negative mean abnormal return, and moreover, the abnormal return was positively correlated with a bank's bailout ratio, defined as the bailout amount divided by its total asset.

4.1. Bank run index during the crisis

Bank run index is constructed by Veronesi and Zingales (2010) using the Credit Default Swap rates, which are available for only a limited number of banks. Bank Run Index measures the difference between the (risk neutral) probability of default

⁶ www.nytimes.com/2008/09/21/business/21draftcnd.html.

⁷ Table C1 in Appendix C shows the timeline for government interventions during the crisis.

⁸ "Wall Street" and the big banks' names frequently appeared in the media and the bill at that time. For example, on October 3rd, when President Bush signed the bill into law, he remarked "By coming together on this legislation, we have acted boldly to prevent the crisis on *Wall Street* from becoming a crisis in communities across our country", which explicitly indicates the big Wall Street banks. For more details, please see <http://www.guardian.co.uk/business/2008/oct/03/creditrunch.useconomy2>.

in the immediately following year and the (risk neutral) probability of default between years 1 and 2, conditional on surviving at the end of year one.

Computation of Bank Run Index

$$R = P(1) - P(2) \tag{12}$$

where

$$P(n) = \text{prob}(\text{Default in year } n | \text{No Default before year } n)$$

Risk neutral default probabilities are bootstrapped from CDS rates. Please refer to the appendix in their paper for the bootstrapping procedure. A higher bank run index stands for a higher probability of bank runs.

Fig. 3 plots the bank run index during the crisis and labels several key events that are related to this paper. These eight banks are among the biggest bailout recipients from TARP. Morgan Stanley experienced a huge volatility of bank run index. Goldman Sachs, Merrill Lynch, Wachovia, Citi also experienced large volatilities of their indices. The volatilities for commercial banks Bank of America, JP Morgan and Wells Fargo were almost zero. Part of the reason for these commercial banks to perform well is an increase of the deposit insurance coverage from \$100,000 to \$250,000 per depositor. The failure of Lehman Brothers on September 15, 2008, increased the bank run index for some banks dramatically. The bankruptcy of Lehman Brothers is the largest bankruptcy filing in U.S. history. Both the counterparty concern and the non-commitment of “Too Big To Fail” policy spurred the bank run index. Nevertheless, the average magnitude of these increases was still much smaller than the effect of \$700 billion bailout proposal from the Treasury Secretary, Henry Paulson. The theory in this paper behind these facts suggests that the \$700 billion bailout signaled to the investors how severe the financial crisis could potentially be, or how toxic banks’ assets actually would be. Immediately after the proposal, there was a “silent” bank run on Washington Mutual, where depositors withdrew their deposits online. Wachovia and Washington Mutual were the top two mortgage lenders at that time. Wachovia experienced a bank run as well, which was almost at the same time. The failure of Washington Mutual is the largest bank failure in U.S. history. The bank run indices kept very high, except for Bank of America, JP Morgan and Wells Fargo, which had less mortgage exposure. The indices did not go down until the announcement of the revised bailout plan which explicitly included the debt guarantee, and thus bank runs happened much less likely, i.e., the bank run indices for these banks dropped steeply.

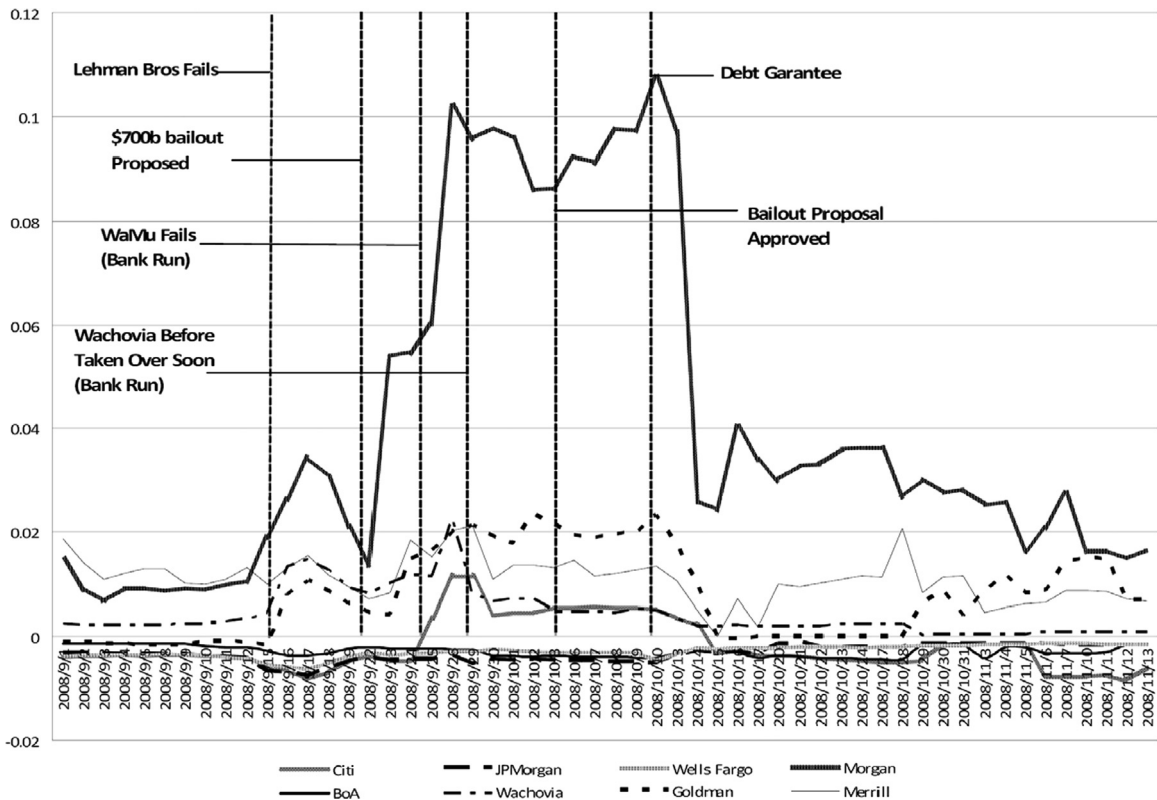


Fig. 3. The run index.

4.2. Data

The data I use for Method 2 in this paper is from multiple sources. For the main bailout information, I assemble the bank level data from Grail research's "Global Financial Crisis: Bailout Tracker" (see [Grail, 2009](#) and [Federal Reserve Bank, 2009](#)), which provide detailed information on bailout enactment dates and bailout amounts. Since some of the enactment dates are different from the announcement dates, I also manually searched the announcement date online including the press releases on the U.S. Treasury department web page. I then gather manually the announcement date of the bailout for each bank. Daily stock prices for all the banks are available at Center for Research in Security Prices at the University of Chicago (CRSP). The data on banks' total assets is from Bankscope.

4.3. Measurement of abnormal returns

Please refer to Appendix D for the measurement details.

4.4. Results

Tables 3 and 4 show that banks exhibited positive abnormal returns most of the time. On the day of announcement, i.e., October 3, 2008, the total sample, including the 241 banks, had insignificant abnormal returns which is close to 0. But largest banks, which were highly expected to be on the bailout list because of "Too-Big-To-Fail", with their names explicitly announced on October 14, 2008, generated significant -3.16% abnormal returns. In Table 3, on days right before the

Table 3

This table reports abnormal returns for a fifteen-day period surrounding the announcement of the recipient unspecified TARP.

Mean abnormal returns (%)				
Day relative to the announcement day (Day 0 = October 3, 2008)	Total sample (Num = 241)	<i>t</i> value	Big banks (Num = 10)	<i>t</i> value
-9	-2.02**	-1.862	-0.45	-0.222
-8	1.04	0.960	1.48	1.085
-7	-0.14	-0.127	-5.68***	-0.341
-6	-0.77	-0.712	-0.09	-0.044
-5	0.46	0.421	3.41**	1.674
-4	1.88**	1.736	-6.30****	-3.095
-3	-1.28	-1.176	10.06****	4.941
-2	2.60***	2.403	7.45****	3.663
-1	3.75****	3.456	2.06	1.014
0	0.05	0.049	-3.16*	-1.552
1	1.22	1.126	0.64	0.314
2	0.17	0.155	-8.08****	-3.972
3	-1.08	-0.993	-2.85*	-1.400
4	-1.41	-1.303	-9.55****	-4.694
5	6.95****	6.408	1.01	0.495

* denotes statistical significance at the 0.10 level using a generic one-tail test.

** denotes statistical significance at the 0.05 level using a generic one-tail test.

*** denotes statistical significance at the 0.01 level using a generic one-tail test.

**** denotes statistical significance at the 0.001 level using a generic one-tail test.

Table 4

This table reports mean cumulative abnormal returns for the fifteen-day period surrounding the announcement of the recipient unspecified TARP.

Mean cumulative abnormal returns (%)				
Day relative to the announcement day (Day 0 = October 3, 2008)	Total sample (N = 241)	<i>t</i> value	Big banks (N = 10)	<i>t</i> value
(0,0)	0.05	0.049	-3.16*	-1.054
(0,1)	1.27	0.831	-2.52	-0.875
(0,5)	5.90**	2.222	-22.00****	-4.413
(-9,5)	11.43****	2.722	-10.06*	-1.276

* denotes statistical significance at the 0.10 level using a generic one-tail test.

** denotes statistical significance at the 0.05 level using a generic one-tail test.

*** denotes statistical significance at the 0.01 level using a generic one-tail test.

**** denotes statistical significance at the 0.001 level using a generic one-tail test.

Table 5

This table reports mean abnormal returns for an eight-day period surrounding the announcements of individual bank bailouts.

Mean abnormal returns for individual banks (%)			
Day relative to the announcement day (Day 0=announcement day)	Total sample (Num = 241)		t value
-2	-0.74*		-1.491
-1	0.38		0.754
0	-0.41		-0.829
1	-0.82**		-1.657
2	-0.84**		-1.693
3	0.12		0.243
4	-0.26		-0.519
5	-0.11		-0.221

* denotes statistical significance at the 0.10, level, using a generic one-tail test.

** denotes statistical significance at the 0.05, level, using a generic one-tail test.

***and

**** denote statistical significance at the 0.01 and 0.001, levels, respectively, using a generic one-tail test.

Table 6

This table reports mean cumulative abnormal returns for an eight-day period surrounding the announcements of individual bank bailouts.

Mean abnormal returns (%)			
Day relative to the announcement day (Day 0=announcement day)	Total sample (N = 241)	Positive:negative	t value
(0,0)	-0.41	(108:133)	-0.829
(0,1)	-1.24**	(98:143)	-1.758
(0,5)	-2.33**	(100:141)	-1.909

*

** denotes statistical significance at the 0.05, level, using a generic one-tail test.

*** and

**** denote statistical significance at the 0.10, 0.01 and 0.001, levels, respectively, using a generic one-tail test

announcement, especially on days of -3 and -2 , there are hefty positive abnormal returns that are also significant which might be due to the leakage of information beforehand or an anticipation of bailouts. For the positive and negative abnormal returns before the announcement on other days, it might be due to the uncertainty of government bailout policy.⁹

These effects are illustrated more clearly by the CAR for the event window (0,5), where investors highly expected that big banks would be bailed out, as pointed out by various media, reporting that the largest banks would be bailed out. The large banks generated very significant negative abnormal returns, which was about -22% , while the banking sector displayed significant 5.9% positive abnormal returns.

Tables 5 and 6 present the abnormal and cumulative abnormal returns for all the banks that received bailouts. Every bank in the sample was bailed out explicitly, i.e., investors knew which banks obtained bailouts and how much. These bailout information can be reached at the U.S. Treasury department and various media sources. The banks experienced negative average abnormal returns, -0.41% for the announcement day, -1.24% for the event window (0,1), and -2.33% for the event window (0,5). The CAR for the two event windows after a bank's individual announcement are significantly negative. Since there is a time lag for investors to receive the information on a bailout, the last event window exhibits a lower abnormal return. The abnormal return before the day '0' was insignificant because a bailout announcement is hard to be predicted. Almost two thirds of banks experienced negative abnormal returns. This supports the conclusion in my model that ex post, after bailout announcements, the probability of bank runs may increase.

Table 7 shows that the bailout ratio, defined as the bailout amount for a bank divided by its total asset, is positively correlated with the abnormal return and the coefficient is significant at the 5% level for the last two windows, even though not for the announcement day, due to information delays.

5. Conclusion

This paper is motivated by various facts listed in the introduction which contradict the conventional wisdom that government bailouts can restore investors' confidence and thus reduce the probability of bank runs. I develop an information based bank run model to examine the effect of bailout announcements on the probability of bank runs. The

⁹ I thank one of the referees for pointing this out.

Table 7

This table reports the effect of bailout on abnormal returns for the announcements of individual bank bailouts.

Bailout ratio and mean abnormal returns (%)			
Event window	(0, 0)	(0, 1)	(0, 5)
Constant	−0.017 (−1.23)	−0.034*** (−3.14)	−0.040*** (−2.84)
Bailout ratio	0.037 (1.18)	0.051** (2.03)	0.069** (2.09)
R ²	0.007	0.02	0.02

*and

** denotes statistical significance at the 0.05, level, using a generic one-tail test.

*** denotes statistical significance at the 0.01, level, using a generic one-tail test.

**** denote statistical significance at the 0.10 and 0.001, levels, respectively, using a generic one-tail test.

model highlights that the signaling effect from government bailouts may increase the probability of bank runs, since bailouts signal the government's information that the bank is in trouble. The model characterizes the probability of bank runs after bailout announcements as a function of bailout amount, government bailout policy and government signal precision. The model also examines whether the existence of such bailout policy is better than the circumstance when the government commits never to bail out banks. I explore the relation between bank runs and TARP bailouts during the recent financial crisis to provide evidence for the theoretical results. From the two measures of the probability of bank runs, I find that bailout announcements generated negative impacts on probabilities of bank runs during the recent crisis. This paper suggests that bailout policy should be carefully designed in order to mitigate the potential bank run probabilities. The empirical evidence implies that the force identified in the theory may be important in practice.

Acknowledgments

This paper is based on my doctoral dissertation submitted to the Graduate School of the University of Minnesota. I am deeply indebted to Larry Jones, Andrew Winton, and especially V.V. Chari for their invaluable guidance. I am very grateful to Pietro Veronesi and Luigi Zingales for providing their code to me. I also thank Murray Frank, Andrew Glover, Chris Phelan, Warren Weber, Wei Xiong, Ariel Zetlin-Jones, two anonymous referees, Eric Leeper (the editor), and seminar participants in the University of Minnesota and Federal Reserve Bank of Cleveland for helpful comments and discussions.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.eurocorev.2013.08.005>.

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