Working Paper Series

Bank Runs and Institutions: The Perils of Intervention

WP 07-02

Huberto M. Ennis
Federal Reserve Bank of Richmond

Todd Keister
Federal Reserve Bank of New York

THE FEDERAL RESERVE BANK OF RICHMOND
RICHMOND ▪ BALTIMORE ▪ CHARLOTTE

Bank Runs and Institutions: The Perils of Intervention

Huberto M. Ennis
Research Department
Federal Reserve Bank of Richmond
Huberto.Ennis@rich.frb.org

Todd Keister
Research and Statistics Group
Federal Reserve Bank of New York
Todd.Keister@ny.frb.org

Federal Reserve Bank of Richmond Working Paper No. 07-02
March 30, 2007

Abstract

Governments typically respond to a run on the banking system by temporarily freezing deposits and by rescheduling payments to depositors. Depositors may even be required to demonstrate an urgent need for funds before being allowed to withdraw. We study *ex post* efficient policy responses to a bank run and the *ex ante* incentives these responses create. Given that a run is underway, the efficient response is typically not to freeze all remaining deposits, since this would impose heavy costs on individuals with urgent withdrawal needs. Instead, (benevolent) government institutions would allow additional withdrawals, creating further strain on the banking system. We show that when depositors anticipate these extra withdrawals, their incentives to participate in the run actually increase. In fact, *ex post* efficient interventions can generate the conditions necessary for a self-fulfilling run to occur.

We thank Roberto Chang and seminar participants at Rutgers University, the Federal Reserve Bank of Richmond, Universidad de Alicante, Universidad de San Andrés, the Society for Economic Dynamics meetings, the Midwest Macro meetings, the North American Meeting of the Econometric Society, the Cornell-Penn State macroeconomics workshop, and the SAET conference in Vigo, Spain, for helpful comments. The views expressed herein are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York, the Federal Reserve Bank of Richmond, or the Federal Reserve System.

1 Introduction

System-wide banking crises are complex phenomena that typically occur in conjunction with a variety of unfavorable financial and macroeconomic factors. One feature that often plays a prominent role in such crises is a *run* by depositors. While the general crisis may develop slowly, over the course of weeks or months, the run is a sudden event in which withdrawals quickly spiral out of control. In Argentina, for example, deposits fell steadily throughout most of 2001, but the rate of withdrawals accelerated dramatically in the last two days of November. Total deposits in the banking system fell by more than 2 billion (U.S.) dollars, or nearly 3%, on November 30 alone.[1]

Such a run almost invariably provokes a policy response from the government and/or central bank. A wide range of responses are possible and, in practice, the details of the response vary across episodes. However, two key elements are typically present. First, at some point deposits are frozen, meaning that further withdrawals are strictly limited. Deposit freezes were a regular feature in U.S. banking history, with the last (and largest) occurring in March 1933, and have been used in recent years in several developing countries.[2] Second, a rescheduling of payments occurs. Some demand deposits, for example, might be converted to time deposits with a penalty for early withdrawal. In addition, depositors may find that their access to funds is made contingent on their ability to demonstrate an urgent need to withdraw; the court system in Argentina was heavily involved in verifying individual depositors' circumstances in 2001-2.

In this paper, we study *ex post* efficient policy responses to a run on the banking system and the *ex ante* incentives these responses give to depositors. In focusing on responses that are *ex post* efficient, we intend to capture institutional features that prevent policymakers from being able to pre-commit to follow a particular course of action in response to a crisis. Instead, the authorities will intervene once the crisis is underway and attempt to bring about the most efficient allocation of resources given the situation. We show how the anticipation of such an intervention can generate the conditions necessary for a self-fulfilling run to occur. In other words, when depositors anticipate that a run will be followed by an (*ex post* efficient) intervention, this fact may

[1] These figures include time deposits with penalties for early withdrawal. Demandable deposits (essentially checking and savings accounts) fell by more than 6% on that day.

[2] Friedman and Schwartz [18] provide an extensive discussion of the nationwide banking holiday of March 1933, as well as of the numerous earlier episodes. Deposits in Argentina were frozen, with some exceptions, for a period of 90 days on December 1, 2001; this freeze was extended in various ways until early 2003. We discuss some details of the intervention in Argentina in Sections 3 and 4 below.

give them *ex ante* incentives to participate in the run. In this sense, such interventions can have a destabilizing effect on the banking system.

Deposit freezes (sometimes called *suspensions of convertibility*) have been studied before, but the focus has been almost exclusively on policies that are *ex ante* efficient. The classic paper of Diamond and Dybvig [10], for example, presented a model in which a self-fulfilling bank run could occur in equilibrium but then showed how an appropriate deposit freeze policy would remove all incentives for depositors to run. In their setting with no aggregate uncertainty, freezing deposits quickly enough in the event of a run guarantees that the banking system will be able to meet all of its future obligations. Given this guarantee, depositors without an urgent need for their funds have no incentive to withdraw and, therefore, a run will never start. Importantly, deposits are never frozen in equilibrium; the threat of a freeze is sufficient to convince depositors not to run. Gorton [21], Chari and Jagannathan [7], and Engineer [13] have also studied deposit freezes, but in each case the focus was again on the policy response that would be chosen *ex ante*, before a crisis were to start.

We show that the deposit freeze studied by Diamond and Dybvig [10] is typically not *ex post* efficient. In other words, if a run started and reached the point where deposits are to be frozen, a benevolent banking authority would not want to follow through with the freeze. The intuition is easy to see. Some of the depositors who have not yet withdrawn truly need access to their funds; freezing deposits imposes heavy costs on these individuals. In most cases, a better policy would be to delay the freeze or reschedule payments in a way that gives at least some funds to these depositors. A banking authority that is unable to pre-commit to follow the complete-freeze policy, therefore, would not choose to do so once a run is underway.

We provide the first analysis of *ex post* efficient policy interventions in the classic Diamond-Dybvig framework. We focus on the types of interventions observed in reality: deposit freezes, payment reschedulings, and court interventions. We show that, compared to the Diamond-Dybvig policy of immediately freezing deposits, the *ex post* efficient policy is more lenient and allows more funds to be withdrawn. Such withdrawals place additional strain on the banking system and decrease the assets available to meet future obligations. This fact, in turn, increases the incentive for a depositor to participate in the run and attempt to withdraw right away. We show that when policy responses are *ex post* efficient, self-fulfilling bank runs can arise in the canonical Diamond-Dybvig model. This result obtains even if the authorities, by means of freezing deposits, are able to halt the run and implement the first-best continuation allocation.

Our results identify an important time-inconsistency problem in banking policy. The banking authorities would like to claim that they will be "tough" in response to a run; this threat, if believed by depositors, would never be tested. However, if a run were to actually start, the authorities would not want to follow through on this threat. Instead, they would choose a more lenient policy that ends up justifying the original decision of depositors to run. This type of time inconsistency was informally discussed by Kydland and Prescott [27, p. 477] in the context of government investment in flood control. As in the Kydland-Prescott example, we show that an inferior equilibrium exists if the government cannot pre-commit to a "tough" course of action.[3]

Our results also contribute to the debate on the underlying causes of observed bank runs. While there are clearly many factors at work in any specific crisis, two distinct views have emerged regarding the basic forces driving these runs. In one view, some fundamental shock(s) cause banks to become insolvent; depositors eventually realize the situation and then rush to withdraw their funds. In this view, a run is always a symptom of the underlying problems in the banking sector.[4] The second view, in contrast, holds that runs can also be caused by the self-fulfilling beliefs of depositors. Individuals may rush to withdraw because they believe the withdrawals of others threaten the solvency of the banking system; the resulting run is a form of coordination failure. In this view, the run is a major contributing factor to the overall crisis, not a mere symptom.

The complexity of real-world banking crises makes it extremely difficult to determine the "true" underlying cause of an observed episode (see Calomiris and Mason [5] and Ennis [14]). One useful research agenda, therefore, is to ask whether or not self-fulfilling runs are plausible, in the sense of being equilibrium outcomes of a reasonable economic model. This agenda began with the seminal work of Bryant [3] and Diamond and Dybvig [10]. As described above, however, self-fulfilling runs can be ruled out in the basic Diamond-Dybvig framework if policymakers can pre-commit to immediately freeze deposits when faced with a run.[5] We show that when the intervention is instead chosen *ex post*, a self-fulfilling run equilibrium can exist. Our approach thus provides one possible answer to the question of "what's missing?" in the Diamond-Dybvig model posed by Green and Lin [23].

---

3 See also the discussion in King [25]. Similar implications of a government's inability to commit are discussed in Glomm and Ravikumar [19], Albanesi, et al. [1], and King and Wolman [26].

4 See, for example, Gorton [21], Saunders and Wilson [29], Calomiris and Mason [4], and Allen and Gale [2].

5 For this reason, the recent literature has focused on more complex environments where aggregate liquidity demand is random (see, for example, Green and Lin [22] and Peck and Shell [28]).

The remainder of the paper is organized as follows. In Section 2 we present the basic model, including banking with demand deposit contracts and deposit freezes. In Section 3 we study the decision of when to freeze deposits in response to a bank run, and we derive conditions under which a self-fulfilling run cannot be ruled out when this decision is made *ex post*, once the run is underway. The focus of Section 4 is on interventions in which the court system determines which depositors have an urgent need to withdraw. We show that such interventions can actually make it *more* difficult for the banking authorities to rule out self-fulfilling runs. We also show that such runs can occur even when the courts are able to implement the first-best continuation allocation *ex post*. Finally, in Section 5 we offer some concluding remarks.

2 The Basic Model

Our basic framework is the now-standard model of Cooper and Ross [8], which generalizes the Diamond and Dybvig [10] environment by introducing costly liquidation and a non-trivial portfolio choice.

2.1 The environment

There are three time periods, indexed by $t = 0, 1, 2$. There is a continuum of *ex ante* identical depositors with measure one. Each depositor has preferences given by

$$u(c_1, c_2; \theta) = \frac{(c_1 + \theta c_2)^{1-\gamma}}{1-\gamma},$$

where c_t is consumption in period t, θ is a binomial random variable with support $\{0, 1\}$, and $\gamma > 0$ holds. If the realized value of θ is zero, the depositor is *impatient* and only cares about consumption in period 1. A depositor's type (patient or impatient) is private information and is revealed to her at the beginning of period 1. Let π denote the probability with which each individual depositor will be impatient. By a law of large numbers, π is also the fraction of depositors in the population who will be impatient. Note that π is non-stochastic; there is no aggregate uncertainty in this model.

The economy is endowed with one unit of the consumption good per capita in period 0. There are two constant-returns-to-scale technologies for transforming this endowment into consumption in the later periods. A unit of the good placed into *storage* in period 0 yields one unit of the good in either period 1 or period 2. A unit placed into *investment* in period 0 yields either $R > 1$ in period

2 or $1 - \tau$ in period 1, where $\tau \in (0, 1)$ represents a liquidation cost. In other words, investment offers a higher long-term return than storage but is relatively illiquid in the short term.

Depositors can pool resources to form a bank,[6] which allows them to insure against individual liquidity risk and minimize costly liquidation. There is also a benevolent banking authority (BA), which has the power to freeze deposits in period 1 if it deems that doing so would increase the welfare of depositors. In Section 4, we introduce a court system that can, once a deposit freeze has been declared, verify depositors' types and, potentially, reschedule payments.

The timing of events is as follows. We begin our analysis with all endowments deposited in the bank.[7] In period 0, the bank divides these resources between storage and investment. In period 1, depositors are isolated from each other and no trade can occur (as described in Wallace [31]). However, each depositor has the ability to contact the bank and, hence, the bank can make payments to depositors from the pooled resources after types have been realized. Depositors choose between contacting the bank in period 1 and waiting until period 2. Those who choose to contact the bank in period 1 do so in a randomly-assigned order; they do not know this order when they decide whether or not to contact the bank.[8] The payment made by the bank to a particular depositor during period 1 can only be contingent on the number of previous withdrawals and not on the actions of depositors who have yet to withdraw. This sequential-service constraint captures an essential feature of banking: the banking system pays depositors as they arrive and cannot condition current payments to depositors on future information. We assume that the BA and the courts are also subject to the sequential-service constraint. Hence, for example, a deposit freeze can only apply to funds that have not yet been withdrawn; it cannot be made retroactive.

2.2 The first-best allocation

In this subsection we provide a benchmark against which the efficiency of the alternative scenarios can be evaluated. Suppose a planner could observe each depositor's type and assign an allocation based on these types. We call the allocation the planner would assign the *first-best allocation*. This

[6] As is standard in the literature, this representative bank can be interpreted as the outcome of competition for deposits (with free entry) in period 0.

[7] For simplicity, we do not examine explicitly the deposit decision of agents (the "pre-deposit game" of Peck and Shell [28]); our approach is the same as that in Diamond and Dybvig [10]. As will become clear later in the paper, our results can be extended to include the pre-deposit game in the usual way.

[8] This assumption, which is standard in the literature, simplifies matters by ensuring that all depositors face the same decision problem, rather than potentially facing different problems depending on their order of arrival at the bank. Most of the results below would also hold if this order were known in advance (see Ennis and Keister [17] for such an analysis).

allocation would clearly give consumption to impatient depositors only in period 1 and to patient depositors only in period 2. Let c_E denote the amount given to impatient depositors (who consume "early") and c_L the amount given to patient depositors (who consume "late"). Let i denote the fraction of the total endowment placed into investment; the remaining $1-i$ would go into storage. Then the planner would choose c_E, c_L, and i to solve

$$\max\ \pi \frac{1}{1-\gamma}\left(c_E\right)^{1-\gamma} + (1-\pi)\frac{1}{1-\gamma}\left(c_L\right)^{1-\gamma}$$

subject to

$$\begin{aligned} \pi c_E &= 1-i, \qquad (1) \\ (1-\pi)c_L &= Ri, \end{aligned}$$

$$c_E \geq 0, c_L \geq 0, \quad \text{and} \quad 0 \leq i \leq 1.$$

The solution to this problem is

$$c_E^* = \frac{1}{\pi + (1-\pi)R^{\frac{1-\gamma}{\gamma}}}, \quad c_L^* = \frac{R^{\frac{1}{\gamma}}}{\pi + (1-\pi)R^{\frac{1-\gamma}{\gamma}}}, \qquad (2)$$

and

$$i^* = \frac{(1-\pi)R^{\frac{1-\gamma}{\gamma}}}{\pi + (1-\pi)R^{\frac{1-\gamma}{\gamma}}}.$$

Notice that $c_L^* > c_E^*$ necessarily holds, meaning that patient depositors consume more than impatient ones.

In order for the possibility of bank runs to arise, the following condition on parameter values must hold.

Assumption 1. $(1-\tau)R^{(1-\gamma)/\gamma} < 1$.

This assumption implies that $c_E^* > 1 - \tau i^*$, or that the amount of consumption given to an impatient depositor in the first-best allocation is greater than the per-capita liquidation value of all assets in period 1. The planner's allocation thus provides *liquidity insurance* by cross-subsidizing those depositors who turn out to be impatient. Notice that this assumption will hold if τ is large (liquidation costs are significant) and/or γ is large (depositors are sufficiently risk averse). We maintain Assumption 1 throughout.

For the remainder of this section and the next, we restrict attention to the case of $\gamma < 1$ so that $u(0, 0; \theta) = 0$ holds. This assumption is used primarily to simplify the exposition. Our results can be generalized to the case of $\gamma > 1$ in a straightforward way by changing the utility function to

$$u(c_1, c_2; \theta) = \frac{(c_1 + \theta c_2 + b)^{1-\gamma} - b^{1-\gamma}}{1 - \gamma} \tag{3}$$

where b is an arbitrarily small scalar.

2.3 Banking with demand deposits

Diamond and Dybvig [10] showed how a bank offering demand-deposit contracts can generate the first-best allocation described above as an equilibrium outcome, even though depositors' types are private information. Suppose the bank allows each depositor to choose whether to withdraw her funds in period 1 or in period 2. It offers depositors withdrawing in period 1 a pre-specified payment c_E (as long as the bank has funds), while depositors withdrawing in period 2 receive a pro-rata share of the matured assets. In effect, the demand-deposit contract generates a game in which each depositor observes her own type and then chooses in which period to withdraw. Note that this arrangement clearly respects the sequential service constraint.

If the bank invests a fraction i^* of its assets and sets the early payment equal to c_E^*, then there is an equilibrium of this game in which the first-best allocation obtains. To see why, first note that an impatient depositor will always choose to withdraw in period 1. A patient depositor, on the other hand, may base her decision on what she expects others to do. If she expects all other patient depositors to wait until period 2 to withdraw, then she anticipates receiving c_E^* if she withdraws early and c_L^* if she waits. Since $c_L^* > c_E^*$ holds (see (2)), her best response is to wait. Hence, there is an equilibrium where all patient depositors wait until period 2 to withdraw and the first-best allocation obtains.

Diamond and Dybvig also pointed out, however, that under this simple deposit contract – absent any intervention – there exists another equilibrium in which all depositors attempt to withdraw in period 1. Suppose an individual patient depositor expects all others (both impatient and patient) to withdraw in period 1. Under Assumption 1 she knows that the bank will not be able to satisfy all of these withdrawal requests. Depositors who contact the bank early enough will receive c_E^*, but a depositor who arrives late in period 1 or waits until period 2 will receive nothing. Her best response in this situation is to also attempt to withdraw in period 1 and, thus, there is an equilibrium where all depositors try to withdraw at once. This equilibrium resembles a run on the banking system.[9]

We say that the banking system is *fragile* if this run equilibrium exists when the period-1 payment on demand deposits is set at c_E^*. Note that fragility does not imply that a run would necessarily occur. If the bank anticipates a run, for example, it might offer depositors a payment different from c_E^* in period 1 in an attempt to prevent the run. The important point is that whenever the banking system is fragile, the *possibility* of a run will generate costly distortions in the economy. These costs can come through an *ex ante* distortion of the banking contract away from the first-best allocation, the *ex post* inefficiency caused by the occurrence of a run, or both. We discuss these issues in more detail in Section 3.3. Here, it suffices to say that only when the banking system is *not* fragile can the potential problems associated with self-fulfilling bank runs be safely ignored. Our interest, therefore, is in whether or not (and under what conditions) deposit freeze policies can eliminate this fragility and ensure that the first-best allocation of resources is achieved.

2.4 Bank runs and deposit freezes

After pointing out the fragility of the simple demand-deposit contract, Diamond and Dybvig showed how a particular deposit freeze policy could make the first-best allocation the *unique* equilibrium outcome. In practice, a deposit freeze is the most common policy response to a banking panic. As mentioned above, such freezes (often called "banking holidays") were a regular occurrence in the U.S. prior to 1933. More recently, Brazil (1990), Ecuador (1999), and Argentina (2001) have declared widespread deposit freezes to stop the outflow of deposits from the banking system (see IMF [24]).

In the model, "normal times" are associated with π withdrawals occurring in period 1. If more than π withdrawals take place in period 1, the BA realizes that a run must be underway and reacts to this information. Suppose it is known that the BA will completely freeze deposits whenever more than π depositors attempt to withdraw in period 1. In other words, after paying the specified amount c_E^* to a fraction π of depositors in period 1, the BA will direct the bank to suspend further payments to depositors until period 2. Diamond and Dybvig [10] showed that this policy rules out the bank run equilibrium and renders the first-best allocation the unique equilibrium outcome in

9 We follow the literature based on the Diamond-Dybvig model in studying deposits that are denominated in real terms. In such case, a sudden increase in withdrawal demand cannot be met by simply printing additional currency, as could be done if contracts were nominal. This assumption matches the situation in many emerging market economies, where a large fraction of deposits are denominated in foreign currencies. (See the discussion in Diamond and Rajan [11].) In Argentina, for example, over 60% of deposits were denominated in U.S. dollars in early 2001.

this economy.

Proposition 1 *(Diamond and Dybvig* [10]*) If deposits are frozen after π withdrawals in period 1, the banking system is not fragile.*

The intuition behind this result is simple. If a patient depositor believes the BA will freeze deposits after a fraction π of depositors has withdrawn in period 1, then she is certain that the bank will have enough resources to pay at least c_L^* in period 2. Since $c_L^* > c_E^*$ holds, waiting to withdraw is a strictly dominant strategy for her, and the only equilibrium has all patient depositors withdrawing in period 2. Note that deposits will never actually be frozen in equilibrium, because a run never takes place. In this way, the BA can costlessly eliminate the possibility of a bank run by means of a temporary deposit freeze.

2.5 Discussion

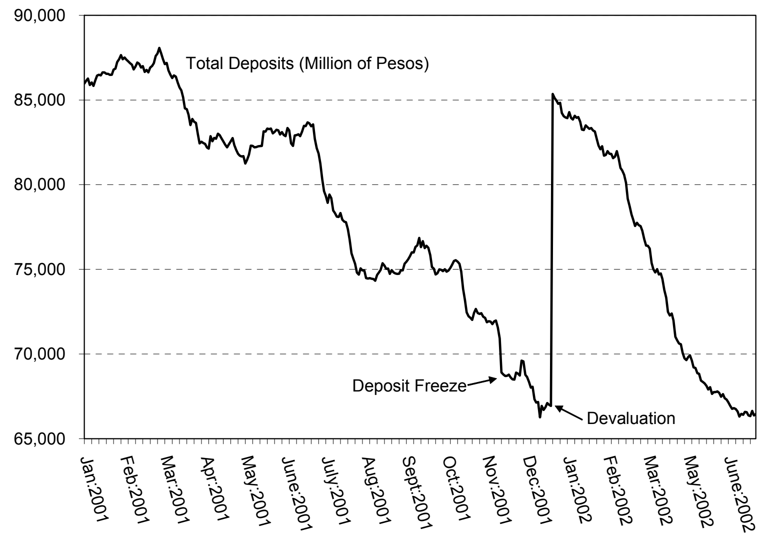
The deposit freezes observed in reality often differ in at least two important ways from the one studied by Diamond and Dybvig [10] and described in our Proposition 1. First, the freeze is usually declared relatively late in the course of the overall crisis. Figure 1 presents the evolution of total bank deposits in Argentina during the crisis of 2001-2. From their peak on February 28, 2001, total deposits had fallen 21.8% by the time the freeze was declared on December 1, 2001.[10] If the deposit freeze in the model is delayed and more than π withdrawals take place in period 1, the payments the bank is able to make in period 2 will decrease. If the freeze is delayed long enough, patient depositors might prefer to participate in the run and the result in Proposition 1 could be overturned.

Second, deposits are often not frozen completely; some types of withdrawals may still be allowed. In Argentina, for example, during the freeze announced on December 1, 2001, depositors were allowed to withdraw up to 1,000 pesos per month from each account. A similar policy was used in Brazil during the freeze implemented in March 1990. In addition, the court system in Argentina ordered banks to make payments to a large number of depositors after the freeze was

[10] The large upward jump in January 2002 corresponds to the abandonment of the currency board and devaluation of the peso. Dollar-denominated deposits, which were approximately 70% of the total, were converted into pesos at the official exchange rate of 1.4 pesos/dollar. This conversion increased total deposits, measured in pesos, by approximately 28%, as depicted in the figure. It is also interesting to note that several run-like events in the summer of 2001 and again in October 2001 did not lead to deposit freezes. In each of these cases, the authorities were able to halt the decline in deposits through various announcements aimed at restoring confidence, such as fiscal adjustment measures and an increase in IMF standy-by credit. See Dominguez and Tesar [12] for details.

in place. Figure 1 shows how total deposits in the banking system in Argentina continued to fall dramatically after the freeze was declared. Such additional payments from the banking system also tend to undermine the incentives for patient depositors to wait and could potentially overturn the result in Proposition 1.

Figure 1: Evolution of Deposits During the Crisis in Argentina 2001-2



Source: Ministry of the Economy and Production of Argentina.

In the remainder of the paper, we investigate why the authorities might choose to allow additional withdrawals when a run is underway, even though these withdrawals place further strain on the banking system. In light of Proposition 1, the BA would clearly like to pre-commit to freezing deposits after π early withdrawals. The experience from crises in Argentina and other countries indicates that institutional factors may limit the ability of the banking authorities to pre-commit to future actions. For this reason, we proceed by assuming that the BA decides interventions only as the crisis develops. To isolate the implications of lack of commitment from other government-induced distortions, we assume the BA reacts *optimally*, given that a crisis is underway. In other words, we focus on policy responses that are *ex post* efficient, and we describe the implications of such policy responses for the fragility of the banking system. We begin by examining the decision of when to declare a deposit freeze.

3 Choosing When to Freeze

In this section, we investigate the incentives a benevolent banking authority faces in deciding when to declare a deposit freeze and how this *ex post* decision, in turn, affects the *ex ante* incentives of depositors to participate in a run. Consider a situation where the bank has already paid out c_E^* to a fraction π of depositors. If additional depositors attempt to withdraw in period $1,$ the BA recognizes that something abnormal is occurring. In our simple model, if more than π depositors attempt to withdraw, a run must be underway. The BA then recognizes that some of the funds already paid out were given to depositors who are actually patient. Furthermore, it knows that some impatient depositors have not yet been served and will be attempting to withdraw. Freezing deposits immediately after π withdrawals implies giving nothing to these impatient depositors, which may be very costly from a social point of view.

3.1 Ex post efficient deposit freezes

When would a benevolent banking authority choose to freeze deposits? Let π_s denote the "freeze point," that is, the fraction of depositors the BA would choose to serve when faced with a run before freezing deposits. Then the BA would seek to maximize depositor welfare by solving the following problem:

$$\max_{\{\pi_s\}} \; W(\pi_s) \equiv \pi_s \frac{1}{1-\gamma}(c_E^*)^{1-\gamma} + (1-\pi_s)(1-\pi)\frac{1}{1-\gamma}\left[c_L(\pi_s)\right]^{1-\gamma} \tag{4}$$

subject to

$$\begin{aligned} c_L(\pi_s) &= \frac{\frac{R}{1-\tau}\left(1-\tau i^* - \pi_s c_E^*\right)}{(1-\pi)(1-\pi_s)} \quad \text{and} \\ \pi_s &\geq \pi. \end{aligned} \tag{5}$$

The objective (4) states that a fraction π_s of depositors will be served in period 1 and each will receive c_E^*. Of the remaining $1-\pi_s$ depositors, only a fraction $1-\pi$ will be patient and return in period 2. The remaining fraction π will be impatient and will receive nothing, leaving them with a utility level of zero. The function $c_L(\pi_s)$ in (5) represents the consumption of patient depositors who are forced by the freeze to return in period 2; the numerator equals the total resources of the bank in period 2 while the denominator is the mass of patient depositors who were not served in period 1.[11] The second constraint reflects sequential service: the BA only discovers that a run is underway after π withdrawals have been made and, thus, π is the earliest possible freeze point.

Let π_s^M denote the solution to this problem, which is implicitly defined by

$$W'\left(\pi_s^M\right) \leq 0, \quad \text{and} = 0 \quad \text{if} \quad \pi_s^M > \pi.$$

In making their withdrawal decisions, depositors recognize that the BA lacks the ability to pre-commit to a specific plan of action and that it will, therefore, react to a run by freezing deposits only after π_s^M withdrawals have been made. Our interest is in whether or not a self-fulfilling run can arise when depositors anticipate this policy response.

3.2 Equilibrium under the efficient policy

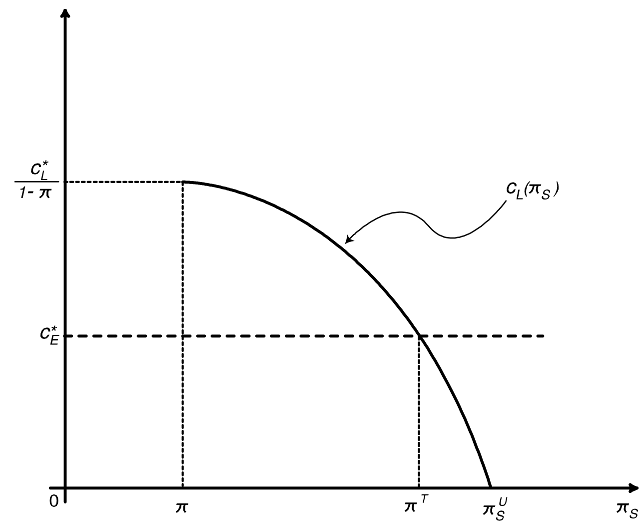
The efficient freeze point π_s^M may be equal to π, in which case Proposition 1 applies and the banking system will not be fragile. In fact, the BA does not need to freeze deposits right at π in order for this result to obtain; it is sufficient for the BA to suspend at any point where it can still afford to give more than c_E^* to depositors who are paid in period 2. Since the function $c_L(\pi_s)$ is strictly decreasing, there is an interval of such values as shown in the following lemma. A proof of this result is given in the Appendix.

Lemma 1 *There exists a value $\pi^T > \pi$ such that if deposits are frozen after π_s withdrawals for any $\pi_s \in [\pi, \pi^T)$, the banking system is not fragile.*

This lemma shows that the effectiveness of a deposit freeze policy in preventing a self-fulfilling run depends crucially on whether the credible freeze point π_s^M is smaller or larger than the threshold value π^T. (See Figure 2.) If it is smaller, the BA will be expected to impose the freeze relatively quickly and $c_L\left(\pi_s^M\right) > c_E^*$ would hold. In such case, a patient depositor – anticipating the "early" freeze – is better off waiting than participating in the run and, hence, a run will never start. However, if π_s^M is greater than π^T, the BA is expected to impose a deposit freeze relatively late and depositors who wait to withdraw during a run will receive less than c_E^*. A patient depositor who expects others to run will, therefore, choose to run as well and a self-fulfilling bank run can arise.

[11] We assume that impatient depositors who are not served in period 1 do not come back to the bank in period 2 since they have no desire to consume. The results would be qualitatively similar if these depositors did contact the BA and receive a share of the remaining funds.

Figure 2: Period 2 Payoff after a Deposit Freeze at π_s



The next proposition is the main result of this section. It shows that for some parameter values, the efficient deposit freeze occurs too late to rule out the possibility of a self-fulfilling run. A proof of the proposition is given in the Appendix.

Proposition 2 *The banking system is fragile under the (ex post) efficient deposit freeze if and only if*

$$\pi \geq \frac{1-\gamma}{\gamma}\left(\frac{R}{1-\tau}-1\right). \tag{6}$$

Condition (6) shows that the banking system will tend to not be fragile if π is small. When relatively few depositors have a real need to consume early, the cost of temporarily freezing deposits and leaving these depositors with nothing is relatively small. In addition, a large proportion of any additional payments made in period 1 during the run would go to depositors who are actually patient. The optimal response to a run in this case is to freeze deposits relatively early and preserve a high payment for the large number of patient depositors expected to come back and withdraw in period 2.[12] Notice that the condition will necessarily be violated if the right-hand side of the inequality is greater than one, or if we have

$$\gamma < 1 - \frac{1-\tau}{R}. \tag{7}$$

[12] It is worth noting that if π is small enough, $W'(\pi) \leq 0$ will hold and the ex post efficient policy will set $\pi_s^M = \pi$. In this case, and only in this case, the BA would choose to follow the policy proposed by Diamond and Dybvig [10] of freezing deposits immediately after identifying a run.

In this case, the efficient deposit freeze occurs early enough to rule out a self-fulfilling run for any value of π. Depositors must exhibit a minimal amount of risk aversion for bank runs to be an issue in this framework.

On the other hand, notice that for any given values of π, R, and τ, condition (6) will hold if γ is close enough to unity. In other words, fixing all other parameter values, the efficient deposit freeze occurs too late to rule out a self-fulfilling run equilibrium if depositors are sufficiently risk averse. We state this result in the following corollary.

Corollary 1 *If depositors are sufficiently risk averse, the banking system will be fragile.*

3.3 Discussion

The results above give conditions under which the banking system is fragile and conditions under which it is not. When it is not fragile (that is, when the equilibrium is unique), this is clearly the end of the story – no bank run will occur and the first-best allocation will obtain. What happens in the fragile case, where the equilibrium is not unique? Would a bank run and the subsequent deposit freeze actually occur? These questions raise the difficult issue of equilibrium selection, a formal analysis of which is beyond the scope of the present paper. However, it is relatively easy to see how the standard approach in the existing literature can be applied to our model and why our results above capture the essential elements at play.

The most common approach to equilibrium selection in this type of model is to assume that depositors condition their actions on the realization of an extrinsic "sunspot" variable; the run equilibrium is played if spots appear on the sun and the no-run equilibrium is played if no spots appear. The probability of a run is then equal to the (exogenous) probability of sunspots. The payment offered by the bank in period 1 may depend on this probability but not on the realization of the sunspot variable, because the latter is not observed by the banking authorities. This approach was suggested in Diamond and Dybvig [10, p. 410] and explicitly taken in Cooper and Ross [8], Peck and Shell [28], and others.

Whether or not a run occurs in equilibrium under this approach depends on both the *ex ante* probability of sunspots and the realization of this variable. If the probability is high, for example, banks may choose to offer a payment much smaller than c_E^* in order to convince depositors not to run. Cooper and Ross [8] labelled such a deposit contract "run proof." Run-proof contracts imply that depositors receive low levels of liquidity insurance and, hence, generate substantially lower welfare than the first-best allocation. For this reason, if the probability of sunspots is low enough then choosing a run-proof deposit contract will not be optimal.[13]

Two main conclusions emerge from this type of analysis. First, whenever the banking system is fragile, an equilibrium can be constructed in which a run occurs with positive probability and all contracting and deposit decisions take this probability into account (see Peck and Shell [28]). In our model, this equilibrium will include a deposit freeze in states where a run occurs.[14] Second, the *ex ante* possibility of a run will lead banks to choose a period-1 payment different from c_E^*, so that the first-best allocation does not obtain even in states where a run/freeze does not occur (see Cooper and Ross [8] and Ennis and Keister [16]).

An alternative approach would be to attempt to use the global-games techniques developed by Carlsson and van Damme [6] and others to eliminate the potential multiplicity of equilibrium. Goldstein and Pauzner [20] show how the Diamond-Dybvig model can be modified for this purpose.[15] However, as is clear from their analysis, using the global-games approach in this setting requires many additional assumptions that would complicate the analysis and distract the focus away from the effects we intend to highlight here. Furthermore, the *ex post* interventions in our framework seem likely to have important effects on the structure of beliefs and, hence, may tend to undermine the uniqueness of equilibrium. Nevertheless, we conjecture that such an exercise, if successful, would lead to the same conclusion as the sunspots-based approach described above: under the conditions we identify in this paper, the possibility of self-fulfilling bank runs distorts the allocation of resources away from the first-best.

The bottom line, therefore, is that whenever the banking system is fragile, the possibility of self-fulfilling runs will create costly distortions in the economy. Our results above characterize the conditions under which this happens if the authorities choose when to freeze deposits in order to maximize (*ex post*) depositor welfare. In the next section we examine what happens when the court system can intervene and verify depositors' types.

---

[13] Ennis and Keister [17] explicitly formulate this argument in a related model. See Ennis and Keister [15] for a general discussion of policy choices and equilibrium selection in environments with strategic complementarities.

[14] In other words, a deposit freeze occurs along the equilibrium path of play in our model. This result contrasts sharply with Diamond and Dybvig [10], where the *threat* of a deposit freeze eliminates the possibility of a run.

[15] In Goldstein and Pauzner [20], pre-commitment is implicitly assumed and the set of possible contracts is exogenously restricted to generate the potential for multiplicity. In our environment, in contrast, multiplicity arises naturally as a result of *ex post* efficient government intervention.

4 Court Intervention

After the authorities declare a deposit freeze, the court system may become involved in the resolution of the crisis. For example, in Argentina in 2001, depositors claiming to have urgent financial needs (due to, for example, illness or hospitalization) could file a legal recourse requesting withdrawal of some or all of their funds from the banking system while the freeze was in place. Nearly 200,000 such cases were filed between December 2001 and June 2003, and the courts awarded payments to depositors totaling over 14 billion pesos (see Table 1). Of the value of total deposits in the system as of March 2002 (around 65 billion pesos) more than 21% were paid out to depositors via legal recourse. This process of legal mediation was based, in part, on the presumption that the courts had at least some ability to differentiate between depositors who needed funds urgently and those who did not. In this section, we investigate how such court interventions can affect the (*ex ante*) fragility of the banking system.

Table 1: Legal Recourses during Deposit Freeze in Argentina 2001-2003

Period	Number of Court Cases	Total Payment (Mill. Pesos)	Total Drop in Banks' Liabilities (Mill. Pesos)	Average Size of Payment (Pesos)
Dec., 2001 - April, 2002	28,430	2,346	1,312	82,518
May - June, 2002	28,285	2,124	1,026	75,093
Dec., 2001 - June, 2002	56,715	4,470	2,338	78,815
July - Dec., 2002	92,926	7,109	3,834	76,502
Jan. - June, 2003	42,249	2,437	1,643	57,682
Total (Dec. 2001 - June 2003)	191,890	14,016	7,815	73,042

Source: Central Bank of Argentina. Note: The term "Court Cases" (*Recursos de Amparo*) stands for court-ordered repayments of individuals' frozen deposits. Banks' deposit liabilities were accounted in pesos after converting dollar deposits into pesos at the official post-devaluation exchange rate of 1.4 pesos per dollar (the liability also includes the indexation called CER). However, some payments to depositors (second column) were made for the dollar amount of the deposits (according to court rule). Hence, total payments (in pesos) tends to be larger than the accounting value (third column).[16]

[16] We are grateful to Fernando Navajas for sharing this data with us.

In the context of our model, suppose that once the BA declares a deposit freeze, the court system intervenes and verifies the true type of each remaining depositor.[17] In principle, one would expect verifying types to involve some administrative costs. To keep the analysis as simple as possible, we abstract from such costs: we assume that type verification occurs costlessly, but only *after* π depositors have already withdrawn and the BA has declared a deposit freeze. This assumption prevents the system from using the courts to completely overcome the private information problem. With a positive verification cost, it would be optimal not to screen the types of the first π individuals to withdraw if the likelihood of facing a run is relatively small. On the other hand, if the cost is not too high, using the verification technology will be desirable *ex post*, after the deposit freeze has been declared.

We consider two cases. First, we assume that the courts insist on giving the promised period-1 payment c_E^* to all impatient depositors. Originally, depositors entered into a contract with the bank stating that they would receive c_E^* if they needed to withdraw early. After the run is discovered, the courts may consider it their duty to maintain this promised value of the early payment. We call this the no-rescheduling case.

Once a run is underway and a deposit freeze has been declared, however, it would be socially optimal to reschedule payments. In particular, it would be optimal to pay the remaining impatient depositors less than c_E^* in order to economize on costly asset liquidation and preserve resources for the patient depositors. In the second case we consider, the courts make this adjustment and thereby are able to implement the first-best *continuation* allocation for the remaining $1 - \pi$ depositors. We call this the case of intervention with payment rescheduling.

The basic logic is similar for the two cases. The courts, by verifying types, ensure that all additional period-1 payments go to agents who truly need to consume early. As a result, the authorities give away more resources in period 1 than they would under a simple deposit-freeze policy, which, in turn, reduces the amount of resources available in period 2. This fact makes waiting to withdraw (*i.e.*, not participating in the run) less attractive to a patient depositor. In other words, by improving the allocation of resources *ex post*, a court intervention can increase the *ex ante* incentive for patient depositors to run and, hence, increase the fragility of the banking system.

[17] Gorton [21] offers a related interpretation of the role of a suspension of payments. He studies an environment where the value of the bank's assets is random and imperfectly observed by depositors. If a suspension of payments triggers a costly state-verification of the value of the assets, then Gorton shows that, in some cases, the suspension can actually be Pareto improving (specifically, in those cases when depositors are more pessimistic than is warranted by the true state of the assets, which is assumed to be known by the entity declaring the suspension).

4.1 No rescheduling of payments

Suppose that once deposits are frozen the courts are expected to intervene, verify which depositors are truly impatient, and honor the original commitment of the bank by awarding c_E^* to each impatient depositor. It is clear that under this expectation, a benevolent BA would declare a deposit freeze immediately after discovering that a run is underway, that is, after π withdrawals in period 1. Once the courts have intervened and verified types, the remaining $\pi(1-\pi)$ impatient depositors will each have received c_E^*. The remaining $(1-\pi)^2$ patient depositors will be paid in period 2; each will receive

$$c_{LC}^* \equiv \frac{R}{(1-\pi)^2}\left(i^* - \frac{(1-\pi)\pi}{(1-\tau)}c_E^*\right).$$

Our interest is in whether or not the conditions necessary for a self-fulfilling run can arise when depositors anticipate this type of court intervention. What action would a patient depositor take at the beginning of period 1 if she expects other patient depositors to run? If $c_{LC}^* > c_E^*$ holds, she would wait until period 2 to withdraw and the run equilibrium would not exist. In this case, the banking system would not be fragile; the combination of a deposit freeze with court intervention would make the first-best allocation the unique equilibrium. Note that in such a case the courts would never intervene in equilibrium; the fact that depositors anticipate this intervention would prevent a run from ever starting. However, if the reversed inequality holds, that is $c_{LC}^* \leq c_E^*$, then a patient depositor expecting a run would choose to withdraw and, hence, the run equilibrium cannot be ruled out. The following proposition characterizes the set of parameter values for which each case applies.

Proposition 3 *The banking system is fragile under a deposit freeze with court intervention and no rescheduling if and only if we have*

$$\pi \geq \frac{(1-\tau)}{R-(1-\tau)}\left(R^{\frac{1}{\gamma}}-1\right). \tag{8}$$

Once again, we see that the banking system will be fragile if there are sufficiently many impatient depositors. It is interesting to compare condition (8) with condition (6) in Proposition 3. Recall that (6) is the necessary and sufficient condition for fragility under an efficient deposit freeze without court intervention. Straightforward algebra shows that when liquidation costs are high, condition (6) is stronger than condition (8). In such cases, there exist intermediate values of π such that (i) without court intervention the (*ex post*) efficient deposit freeze prevents banking system fragility, but (ii) with court intervention the banking system is fragile. We formalize this result in the following proposition. The proof is straightforward and thus omitted.

Proposition 4 *Given all other parameter values, there exists $\hat{\tau} \in [0, 1)$ such that for all $\tau \geq \hat{\tau}$, condition* (8) *holds but condition* (6) *is violated for an interval of values for π.*

In other words, court intervention can undermine the BA's ability to ensure, by freezing deposits, that the most desirable allocation is the unique equilibrium. The logic is simple. When the BA anticipates a court intervention, it declares a deposit freeze quickly (immediately after discovering the run) but the courts still mandate payments to impatient depositors in period 1. If liquidation costs are high, making these payments is very costly and the funds available for period 2 payments are highly depleted. Instead, if court intervention is not possible, while the BA may delay the freeze of deposits, after the freeze is declared no further payments are made in period 1. This complete halt in payments reduces the total payout (and early liquidation) in period 1 and thus allows a relatively high payment to those depositors withdrawing in period 2. The anticipation of high payments in period 2 makes running no longer an equilibrium strategy.

We can go a step further and ask whether or not the (benevolent) BA would actually want the courts to intervene. Proposition 4 shows that, at least for some parameter values, in period 0 the BA would like to obtain a prior commitment from the courts that they would not intervene in the event of a freeze. However, it is not difficult to show that for some of these same parameter values, once a run is discovered in period 1 the BA would prefer to have the courts intervene because such intervention leads to a better allocation of resources. In this sense, the possibility of court intervention introduces a new kind of time-inconsistency problem. Even in cases where a credible deposit freeze would be able to eliminate the possibility of a bank run, the inability to credibly rule out a court intervention in the event of a run could render the banking system vulnerable to a run.

4.2 Payment rescheduling

The intervention policy studied above involves a somewhat artificial restriction: the courts insist on repaying the amount c_E^* originally promised to depositors withdrawing in period 1. We now relax this restriction and allow the courts to reschedule payments if they conclude that doing so can improve depositor welfare.

As before, the bank pays c_E^* to the first π depositors who withdraw in period 1. If more than π depositors attempt to withdraw in period 1, the BA realizes that a run is underway and will choose to immediately declare a deposit freeze. Once the freeze is in place, the courts intervene and verify which depositors are truly impatient. The only difference from the earlier case is that we now allow the courts to decide how much each of the remaining impatient depositors should be paid in period 1. This payment is chosen to solve the following problem:[18]

$$\max_{c_E, c_L, i} (1-\pi) \left[\pi \frac{1}{1-\gamma} (c_E)^{1-\gamma} + (1-\pi) \frac{1}{1-\gamma} (c_L)^{1-\gamma} \right]$$

subject to

$$\begin{aligned} (1-\pi)\, \pi c_E &\leq (1-\tau)\, i^*, \\ (1-\pi)^2 c_L &= R \left[i^* - \frac{(1-\pi)\, \pi c_E}{(1-\tau)} \right], \end{aligned}$$

$$c_E \geq 0 \text{ and } c_L \geq 0.$$

Of the $1-\pi$ remaining depositors, a fraction π are impatient and will be served in period 1 while a fraction $1-\pi$ are patient and will be told to come bank in period 2. The first constraint in the problem reflects the fact that all of the resources in storage have already been paid out to the first π depositors who withdrew; additional period-1 payments can only come from liquidating investment. The second constraint is the standard pro-rata share of remaining resources that determines the payment in period 2. The solution to this problem is given by

$$c_{ER}^* = \frac{1}{\pi + (1-\pi)\, \widehat{R}} \frac{(1-\tau)\, i^*}{(1-\pi)} \quad \text{and} \quad c_{LR}^* = \left(\frac{R}{1-\tau} \right) \frac{\widehat{R}}{\pi + (1-\pi)\, \widehat{R}} \frac{(1-\tau)\, i^*}{(1-\pi)} \tag{9}$$

where

$$\widehat{R} = [R/(1-\tau)]^{(1-\gamma)/\gamma}.$$

Note that $c_{LR}^* > c_{ER}^*$ holds.[19]

At the beginning of period 1, depositors anticipate that the BA will respond to a run by declaring a freeze, triggering a court intervention and resulting in the continuation payments (c_{ER}^*, c_{LR}^*).

[18] Note that the solution to this problem is the first-best allocation for the continuation economy after π agents have each received c_E^* from the banking system.

[19] Note that in the analysis that follows, there are no circumstances in which some depositors receive zero consumption and, therefore, we can study the case where the coefficient of relative risk aversion is greater than one without changing the form of the utility function to (3).

Given these payments, would a patient depositor choose to run at the beginning of period 1 if she believes that all other depositors will? A patient depositor who believes that all other depositors are running will have an expected payoff of

$$\pi\frac{1}{1-\gamma}\left(c_E^*\right)^{1-\gamma}+(1-\pi)\frac{1}{1-\gamma}\left(c_{LR}^*\right)^{1-\gamma}$$

if she also runs, but will receive c_{LR}^* for certain if she does not run. Using (2) and (9), it is straightforward to show that $\gamma \leq 1$ implies that $c_{LR}^* \geq c_L^* > c_E^*$ holds and, therefore, the depositor would prefer not to run. In other words, the run equilibrium cannot exist when γ is less than unity. We summarize this discussion in the following proposition.

Proposition 5 *For $\gamma \in (0,1]$, under a deposit freeze with court intervention and payment rescheduling the banking system is not fragile.*

Proposition 5 shows that if the coefficient of relative risk aversion is less than unity then, regardless of the size of the liquidation cost, the possibility of a deposit freeze followed by a court intervention that reschedules payments will allow the economy to achieve the first-best allocation without raising the possibility of a self-fulfilling run. In addition, it is straightforward to show that $\gamma < 1$ implies $(1-\pi)\,c_{ER}^* \leq (1-\tau)\,i^*$. In other words, even if the courts would assign c_{ER}^* in period 1 to *all* remaining depositors, there would be enough liquidity in the system to cover those payments. This fact, in turn, implies that even if the courts were not to verify types after the intervention, only impatient depositors would appeal to the courts to obtain the early payment c_{ER}^*. In a sense, verification of types is redundant in this case.[20]

Things are different when $\gamma > 1$. In this case, it is possible for $c_{LR}^* \leq c_E^*$ to hold and, hence, for a patient depositor to choose to run when she expects others to do so. Straightforward algebra shows that this condition is equivalent to the following:

$$R^{\frac{1}{\gamma}}\frac{\left(\frac{R}{1-\tau}\right)^{\frac{1-\gamma}{\gamma}}}{\pi+(1-\pi)\left(\frac{R}{1-\tau}\right)^{\frac{1-\gamma}{\gamma}}} \leq 1. \tag{10}$$

We can now state the main result of this section.

[20] The payments (c_{ER}^*, c_{LR}^*) constitute a run-proof contract (Cooper and Ross [8]). Even if agents expect the courts to be lenient in their verification of types (i.e., in determining who has urgent needs and who does not), the payoff c_{ER}^* is low enough that there is no danger of a "run" to the courts.

Proposition 6 *The banking system is fragile under a deposit freeze with court intervention and payment rescheduling if and only if* (10) *holds.*

Notice that (10) will necessarily be violated if π is close to zero, which is reminiscent of Proposition 2 in the previous section. When there are relatively few impatient depositors, the additional early payments ordered by the courts amount to a relatively moderate sum and, hence, there will be sufficient assets left to offer a relatively high payment to depositors in period 2. Also notice that, consistent with Proposition 5, condition (10) cannot hold if γ is less than unity. However, if γ is greater than unity then, given all other parameter values, for high enough values of the liquidation cost τ the condition will hold. In other words, if the coefficient of relative risk aversion is greater than one, whenever liquidation costs are large the banking system will be fragile.

Corollary 2 *For any* $\gamma > 1$, *there exists a* $\overline{\tau} < 1$ *such that* $\tau \geq \overline{\tau}$ *implies that the banking system is fragile under a deposit freeze with court intervention and payment rescheduling.*

Villamil [30] suggests that a way to commit to a full suspension of payments is by making investments that cannot, under any circumstances, be liquidated (and shows how the optimal lending contract can have this property in some settings). This idea can be captured in our notation by setting $\tau = 1$, in which case suspending payments after all liquid assets have been depleted is clearly *ex post* efficient. However, Corollary 2 points out the knife-edge nature of this argument. If liquidation is costly but not impossible (*i.e.*, τ is close to but not equal to 1), the courts will still mandate the liquidation of some investment after a deposit freeze and the possibility of a run cannot be ruled out.

Given a value of the liquidation cost (and all other parameter values), condition (10) will also hold if γ is large enough. The result in Proposition 6 can, therefore, be stated another way: the first-best allocation cannot be obtained without introducing the possibility of a run if depositors are sufficiently risk averse.

Corollary 3 *There exists* $\overline{\gamma} < 0$ *such that* $\gamma \leq \overline{\gamma}$ *implies that the banking system is fragile under a deposit freeze with court intervention and payment rescheduling.*

5 Concluding Remarks

The previous literature on bank runs has concluded that self-fulfilling runs can typically be prevented if there is enough flexibility in the scheme for setting payments to depositors.[21] In light of this finding, it seems natural to conjecture that any viable explanation of self-fulfilling runs will require taking into consideration institutional restrictions that might limit such flexibility. Our focus has been on a set of realistic, *ex post* efficient interventions that can be regarded as providing microfoundations for such limitations. The results presented in the previous literature rely on the ability of the banking authorities to pre-commit to a specific payment arrangement. In this paper, we argue that to better understand many of the relevant situations, it is more appropriate to proceed under the premise that pre-commitment is not possible and, hence, that interventions and actual payments are decided as events unfold. In this case, many of the previously proposed schemes are no longer feasible and self-fulfilling runs become a real possibility.

The behavior of individuals during a banking crisis depends crucially on how they expect the authorities to respond to events. If it were known that the authorities would respond to a run by immediately freezing all remaining deposits then, in a wide range of model environments, self-fulfilling runs would not happen. However, this type of response is likely to be highly inefficient ex post, in the event that a run actually occurs. Taking into account these ex post concerns can dramatically change the analysis. We illustrated this fact by deriving the *ex post* efficient policy responses to a run in the classic framework of Diamond and Dybvig [10] and showing how these interventions can actually generate the *ex ante* incentives that induce depositors to participate in a run.

Banking crises are often associated with periods of significant political turmoil and weak institutions, which makes any sort of commitment by government agencies difficult to achieve. Such was certainly the case in Argentina, with the President of the country resigning in December 2001 and his successor resigning after only a week in office. Political stability was also present in the U.S. during the banking crisis of 1932-33, when a change in administration made commitment to a coherent policy very difficult (see Friedman and Schwartz [18] pp. 327-331). In addition, a suspension of payments from the banking system effectively requires commitment from multiple branches of government, which is especially difficult to achieve. The executive branch in

[21] See, for example, de Nicolò [9] and Green and Lin [22].

Argentina, for example, could not prevent the court system from allowing additional withdrawals after the deposit freeze was declared.

These institutional features that undermine the ability of a government to pre-commit to a given course of action correspond to precisely the type of problems we aim to draw attention to with our analysis. We have shown that when depositors anticipate the government's *ex post* reaction, they often have an *ex ante* incentive to run on the banking system if they expect others to do so as well. Our general conclusion from this novel approach is that, to the extent that lack of commitment is a realistic feature of economies in crisis, the possibility of self-fulfilling runs cannot be safely ignored from the standpoint of modern banking theory.

Appendix A. Proofs

Lemma 1: There exists a value $\pi^T > \pi$ such that if deposits are frozen after π_s withdrawals for any $\pi_s \in [\pi, \pi^T)$, the banking system is not fragile.

Proof: Define the function $c_L(\pi_s)$ as in (5). This function gives the payoff to a patient depositor who waits until period 2 to withdraw when (i) all other patient depositors attempt to withdraw in period 1 and (ii) the BA declares a deposit freeze after a proportion π_s of depositors have withdrawn. Note that we have

$$c_L(\pi) = \frac{c_L^*}{(1-\pi)} > c_L^* > c_E^*.$$

It is straightforward to show that $dc_L(\pi_s)/d\pi_s < 0$ holds. In addition, there exists a value $\pi_s^U < 1$ such that $c_L(\pi_s^U) = 0$; this value is given by $\pi_s^U \equiv 1 - \tau i^*/c_E^*$. Hence, there is a unique value π^T such that $\pi_s < \pi^T$ implies $c_L(\pi_s) > c_E^*$, while $\pi_s > \pi^T$ implies $c_L(\pi_s) < c_E^*$. (See Figure 2.) Therefore, waiting is a strictly dominant strategy for patient depositors if and only if $\pi_s \in [\pi, \pi^T)$.

□

Proposition 2: The banking system is fragile under the (ex post) efficient deposit freeze if and only if (6) holds.

Proof: Define

$$A(\pi_s) \equiv \frac{c_L(\pi_s)}{c_E^*}. \tag{11}$$

Using (1) and (5), this expression can be written as

$$A(\pi_s) = \frac{(1-\pi) R^{\frac{1}{\gamma}} - (\pi_s - \pi) \frac{R}{1-\tau}}{(1-\pi_s)(1-\pi)}. \tag{12}$$

Using (11), the BA's objective function (4) can be rewritten as

$$W(\pi_s) = \frac{(c_E^*)^{1-\gamma}}{1-\gamma} \left(\pi_s + (1-\pi_s)(1-\pi) A(\pi_s)^{1-\gamma} \right).$$

It is straightforward to show that W is strictly concave. Using (12), its derivative can be written as

$$W'(\pi_s) = \frac{(c_E^*)^{1-\gamma}}{1-\gamma} \left[1 - \gamma (1-\pi) A(\pi_s)^{1-\gamma} - (1-\gamma) \frac{R}{1-\tau} A(\pi_s)^{-\gamma} \right]. \tag{13}$$

The banking system is fragile under the (ex post) efficient deposit freeze if and only if $\pi_s^M \geq \pi^T$ holds, or (by the concavity of W) if and only if we have

$$W' \left(\pi^T\right) \geq 0.$$

Using (13) and the fact that $A\left(\pi^T\right) = 1$ holds (see (11) and Figure 2), this condition becomes

$$1 - \gamma\left(1 - \pi\right) - \left(1 - \gamma\right) \frac{R}{1 - \tau} \geq 0.$$

Straightforward manipulations then yield condition (6). □

References

[1] Albanesi, Stefania, V.V. Chari, and Lawrence J. Christiano, "Expectation traps and monetary policy," *Review of Economic Studies* 70 (2003), 715-741.

[2] Allen, Franklin and Douglas Gale, "Optimal financial crises," *Journal of Finance* 53 (1998), 1245–1284.

[3] Bryant, John, "A model of reserves, bank runs, and deposit insurance," *Journal of Banking and Finance* 43 (1980), 749–761.

[4] Calomiris, Charles W. and Joseph R. Mason, "Contagion and bank failures during the great depression: The June 1932 Chicago banking panic," *American Economic Review* 87 (1997), 863-883.

[5] Calomiris, Charles W. and Joseph R. Mason, "Fundamentals, panics and bank distress during the depression," *American Economic Review* 93 (2003), 1615-1647.

[6] Carlsson, Hans and Eric van Damme, "Global Games and Equilibrium Selection," *Econometrica* 61 (1993), 989-1018.

[7] Chari, V.V. and R. Jagannathan, "Banking Panics, Information, and Rational Expectations Equilibrium," *Journal of Finance* 43 (1988), 749-761.

[8] Cooper, Russell and Thomas W. Ross, "Bank runs: liquidity costs and investment distortions," *Journal of Monetary Economics* 41 (1998), 27-38.

[9] de Nicolò, Gianni, "Run-proof banking without suspension or deposit insurance," *Journal of Monetary Economics* 38 (1996), 377-390.

[10] Diamond, Douglas W. and Phillip H. Dybvig, "Bank runs, deposit insurance, and liquidity," *Journal of Political Economy* 91 (1983), 401-419.

[11] Diamond, Douglas W. and Raghuram G. Rajan, "Money in a theory of banking," *American Economic Review* 96 (2006), 30-53.

[12] Dominguez, Kathryn M. E. and Linda L. Tesar, "International borrowing and macroeconomic performance in Argentina," in *Capital Controls and Capital Flows in Emerging Economies: Policies, Practices, and Consequences*, edited by Sebastian Edwards, University of Chicago Press for the NBER, forthcoming (2006).

[13] Engineer, Merwan, "Bank runs and the suspension of deposit convertibility," *Journal of Monetary Economics* 24 (1989), 443-454.

[14] Ennis, Huberto M., "Economic Fundamentals and Bank Runs," Federal Reserve Bank of Richmond *Economic Quarterly* 89 (2003), 55-71.

[15] Ennis, Huberto M. and Todd Keister, "Government policy and the probability of coordination failures," *European Economic Review* 49 (2005), 939-973.

[16] Ennis, Huberto M. and Todd Keister, "Bank runs and investment decisions revisited," *Journal of Monetary Economics* 53 (2006), 217-232.

[17] Ennis, Huberto M. and Todd Keister, "Commitment and Equilibrium Bank Runs," Federal Reserve Bank of New York Staff Report No. 274 (2007).

[18] Friedman, Milton and Anna Jacobson Schwartz, *A Monetary History of the United States, 1867-1960*. Princeton University Press (1963).

[19] Glomm, Gerhard and B. Ravikumar, "Endogenous public policy and multiple equilibria," *European Journal of Political Economy* 11 (1995), 653-662.

[20] Goldstein, Itay and Ady Pauzner, "Demand deposit contracts and the probability of bank runs," *Journal of Finance* 60 (2005) 1293-1327.

[21] Gorton, Gary, "Bank suspension of convertibility," *Journal of Monetary Economics* 15 (1985), 177-193.

[22] Green, Edward J. and Ping Lin, "Implementing efficient allocations in a model of financial intermediation," *Journal of Economic Theory* 109 (2003), 1-23.

[23] Green, Edward J. and Ping Lin, "Diamond and Dybvig's classic theory of financial intermediation: What's missing?" Federal Reserve Bank of Minneapolis *Quarterly Review* 24 (2000), 3-13.

[24] International Monetary Fund, "Sovereign Debt Restructurings and the Domestic Economy. Experience in Four Recent Cases," prepared by the Policy Development and Review Department, February 2002.

[25] King, Robert G., "Discretionary policy and multiple equilibria," Federal Reserve Bank of Richmond *Economic Quarterly* 92 (2006), 1-15.

[26] King, Robert G. and Alexander L. Wolman, "Monetary discretion, pricing complementarity, and dynamic multiple equilibria," *Quarterly Journal of Economics* 119 (2004), 1513-1553.

[27] Kydland, Finn E. and Edward C. Prescott, "Rules rather than discretion: the inconsistency of optimal plans," *Journal of Political Economy* 85 (1977), 473-492.

[28] Peck, James and Karl Shell, "Equilibrium bank runs," *Journal of Political Economy* 111 (2003), 103-123.

[29] Saunders, A. and B. Wilson, "Contagious Bank Runs: Evidence from the 1929-1933 Period," *Journal of Financial Intermediation* 5 (1996), 409-423.

[30] Villamil, Anne, "Demand deposit contracts, suspension of convertibility, and optimal financial intermediation," *Economic Theory* 1 (1991), 277-288.

[31] Wallace, Neil. "Another attempt to explain an illiquid banking system: the Diamond and Dybvig model with sequential service taken seriously," *Federal Reserve Bank of Minneapolis Quarterly Review* 12 (Fall 1988), 3-16.