# On the Severity of Bank Runs: An Experimental Study

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**Abstract**

This paper investigates the factors that determine the severity of bank runs and points out possible policies that might help dampen them. We have demonstrated that in general the more information economic agents can expect to have about an ongoing financial crisis, i.e. the more they can expect to learn about the crisis as it develops, the more willing they are to restrain themselves in withdrawing their funds from banks once a crisis actually occurs. In addition, we show that deposit insurance, even of a limited type, can also help to diminish the severity of bank runs. Finally, we see that the presence of insiders who know the quality of the bank their money is invested in, is welfare increasing in the sense that when such insiders exist, subjects tend to withdraw their money later than they would if no such insiders exist.

## 1. Introduction

For those of us living in the United States, there seems to be a perception that things like bank runs and other types of financial crises are no longer a matter of concern. The reality is that bank runs are still a constant feature of economies throughout the world. Lindgren, Garcia and Saal (1996) show that during the period 1980-96, of the 181 IMF member countries, 133 have experienced significant banking problems. Such problems have affected developed, as well as developing and transitional countries. For example, over the past 25 years banking crises have hit such developed countries as Finland (1991-93), Norway (1988-92), Japan (1992-present), Spain (1977-85), and Sweden (1991) and have recently troubled such developing countries as Russia (1998), Brazil (1999), Turkey (2000) and (2001) and Argentina (2001), and various counties in Asia (1997-98). These banking problems also have significant costs as many authors have documented (see, Lindgren, Garcia and Saal (1996), Caprio and Klingebiel (1996), Lindgren et.al. (1999),

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Alexander et.al. (1997), Sundararajan and Baliño (1991), Hoggarth, Reis and Saporta (2001)).

When one looks at the economic literature on bank runs (Diamond and Dybvig (1983), Allen and Gale (1998), Calomiris and Kahn (1991), Chari and Jagannathan (1988) and others) one sees a wide variety of models most of which have the same two features. With some variations, most of the models on bank runs are static two-period equilibrium based models with a continuum of agents played in the normal or simultaneous move form. In many of these models, the bank run problem is viewed as an equilibrium selection problem embedded in a coordination game in which all agents would be better off if they did not create a run on the bank (remove their money early) while it is an equilibrium to both remove early and to remove late. In addition, they mainly focus on whether deposit contracts are optimal arrangements in the presence of the possibility of a bank run and try to find the Central Bank policy and other institutional arrangements to prevent runs or minimize the cost associated with them.

But Brunnermeier (2001) makes an important observation about the bank run models in the economic literature: “Although withdrawals by deposit holders occur sequentially in reality, the literature typically models bank runs as a simultaneous move game”. And, since most of these models are static, they do not attempt to explain the severity of bank runs. In these models, bank runs either occur or they do not. But as we know, some bank runs are more severe than others and most of the theoretical literature on bank runs appears to be silent about such questions.

We concentrate on the severity of bank runs measured by how fast money is removed from the banking system after a crisis has developed and ask questions like:

- Are bank runs more severe (i.e. does money get withdrawn from the system more quickly) when depositors observe the action of other depositors and can see when they withdrew their money and how much they received?

- Are runs more severe when some depositors have insider information?

- Is the severity of bank runs influenced by cyclical factors in the economy, i.e., should we expect them to be more severe if they occur when the economy is in a down-cycle?

- Can partial deposit insurance be as effective as the usual full insurance in mitigating the severity of bank runs?

Some of these questions cannot be answered with two-period static models. Though there are some experimental studies on similar issues such as network formation and contagion, an excellent one being Corbae and Duffy (2002), micro data on most of these issues do not exist. Therefore we chose to examine these issues in the context of experiments using a dynamic model.

In this paper we look at the dynamics of bank runs and try to sort out what influences their occurrence and what interventions work in slowing them down. We basically look at two types of interventions - informational and insurance. With respect to the first we are interested in knowing whether there is certain information which, if released during the progress of a bank run, could slow it down. Such information, for example may be information about whether those who have removed their money from the bank were paid or not.

The insurance question we ask is how little insurance is needed to stop bank runs. The idea here is that full insurance may not be needed to stop bank runs and is not even desirable since in the presence of full insurance, depositors do not have any incentive to differentiate between sound and unsound banks. Weak banks do not have any difficulty in attracting deposits. This creates an opportunity for moral hazard on banks' side[1]. Garcia (2000) recommends providing low coverage as a good practice but suggests that we also need to answer such questions as which deposits should be covered and at what level. In that context, our study is an attempt to discover which level of coverage is optimal. Hence, we test whether partial deposit insurance can prevent runs.

Finally, we investigate the role of asymmetric information in our bank run model. Here some set of agents or subjects are "insiders" who are informed of the state of the world (how sound their bank is) while others are not. We ask whether the presence of such insiders exacerbates or dampens the severity of bank runs during a crisis.

We embed our experiment in a four period bank run model whose equilibria we calculate. The fact that we have four periods, instead of the usual two, allows us to investigate the dynamics of bank runs more easily than a two period model would.

Our experiments turn up a number of interesting findings that inform both theory and policy. First we find that bank-run behavior is influenced by the information that subjects have on hand when a crisis occurs. For example, in one treatment we run the experiment using a simultaneous play version or the normal form where all subjects choose when to withdraw their money from a bank at once and in ignorance of what the other subjects are doing. In another treatment they play the game in the extensive form where over a four-period horizon they decide period by period if they want to remove their money conditional on what has happened before them, i.e., how many people removed their money and what their payoffs were. We find that behavior is consistent with the predictions of the theory mostly when the game is played in the extensive form with high amounts of information given between periods (information describing how many people removed their money, what payoff they received etc.). This is despite the fact that behavior should be invariant to the game form. Since in the real world bank runs are

[1] Some argue that guarantees create distortions and make bank failures more likely. Demirguc-Kunt and Detragiache (2000) analyzes panel data for 61 countries during 1980-97 and concludes that "explicit deposit insurance tends to be detrimental to bank stability, the more so when institutional environment is weak, when the coverage is extensive and when the insurance is run by the government".

more typically played in the extensive form, this finding lends support to using theory as a guide to behavior[2].

Second, we find that it is possible to delay or slow down bank runs by issuing minimal deposit insurance. More precisely, in some of our experiments we insure depositors by issuing insurance which covers either 20% or 50% of what is owed them. We find that even with this minimal coverage, the withdrawal timing is significantly delayed. This is important, of course, since issuing full deposit insurance by the government (up to $100,000) is both costly and creates adverse incentives for depositors, that is, depositors fail to engage in diligence when selecting a bank. On the other hand, partial insurance creates an incentive for consumers to monitor their banks.

Third, we show both theoretically and empirically that the presence of insiders actually increases welfare by leading subjects to remove their money later rather than sooner. Hence, ceteris paribus, money stays in the banking system longer when there is private insider information and that is a benefit in our model.

Finally, we also present evidence that the severity of a bank run depends on the state of the economy when a crisis occurs. More precisely, say that a consumer wakes up one morning picks up a newspaper and reads that there is a possibility of a banking crisis. If this news arrives when the economy is doing relatively well, i.e. when the mean rate of return in the banking industry is relatively high, then we would expect (and we find) that the severity of the banking crisis is less than when this news arrives during a downturn.

In this paper we will proceed as follows: In Section 2 we present the bank run model that underlies our experiment. In Section 3 we describe our experimental design and procedures. In Section 4 we describe theoretical results while in Section 5 we present our empirical findings. In Section 6 we describe our learning results and we present some conclusions and speculations in Section 7.

## 2. A Bank Crisis Model

Consider a community of six people all of whom deposit their money in the same bank. While this bank may have served them well in the past, they have no idea how the bank invests its money and hence they are never sure whether it can meet its obligations if called on to do so. To make this uncertainty more transparent assume that there are five types of banks in the economy, $B_1$, $B_2$, $B_3$, $B_4$ and $B_5$. We are calling Bank $B_3$ the mean bank $B_m$ since it has a rate of return on its money that is the mean return in the five-bank banking industry. The other banks, $B_1$, $B_2$, $B_4$ and $B_5$, are banks whose rate of returns are 1/3 $B_m$, 2/3 $B_m$, 4/3 $B_m$, 5/3 $B_m$ respectively. What this means is that if the community's money is in the worse type of bank that bank earns a rate of return on its money equal to 1/3 $B_m$ or 1/3 of the mean rate of return in the banking industry. Banks 4 and 5 are the better than average banks, those who have invested well. The bank that the community's

2 See Brunnermeier (2001). Some exceptions would be Chen (1999), Green and Lin (2001) and Yorulmazer (2002).

money is in is drawn randomly with a uniform density $f_b = 1/5$, b = 1,2,3,4,5, so that the probability that any given bank is the relevant one is 1/5.

Assume that time is divided into 4 discrete periods 1, 2, 3 and 4 and, that all money must be withdrawn at the end of the fourth period if it is kept there that long. This is a stylized version of a bank crisis since it requires that agents think of when they should withdraw their money knowing that the other agents are thinking about the same thing. The need to think about removing your money may have been caused by an external event which is left un-modeled here (a newspaper headline that a major bank has failed elsewhere or major embezzlements discovered by the press). So this is a model of an existing bank crisis since the question is not whether an agent should remove his money from the bank but, rather, when.

The bank promises to pay a promised rate of return on the money deposited in it of r' and will do so if it has the funds to pay when people request them. If it does not, then it will pay each person who wants to withdraw, an equal share of what it has on hand.

Each person starts off with $K to deposit and if it keeps its money in the bank for $l$ periods she will be paid $V = \$(1+r')^l K$ if the bank has that amount of money on hand to pay all the people who want to withdraw at that time. If not, it pays them an equal share of what it has on hand.

This scenario defines a game. In this game nature makes the first move and selects a bank where all the money is deposited. The type of bank is chosen randomly and is not revealed to the agents; they only know the distribution. When played in the normal form, this game has a strategy set consisting of the four integers {1,2,3,4} representing the four time periods at which money can be withdrawn and the expected payoff function,

$$E\pi_{it} = E_b\,(\pi\,(t, n_1,\ldots,n_t, b, r', 6K))$$

where b is the randomly selected bank and the expectation is over five possible banks selected randomly from a uniform density $f_b = 1/5$, b = 1,2,3,4,5.

This payoff function has the following interpretation: It defines the expected payoff to player $i$ removing her money in period $t$ depending on the time period $t$ the money is withdrawn, the vector of withdrawals up until and including time $t$, denoted by, $n_1,\ldots,n_t$ where, $n_t$ is the number of players withdrawing in period $t$, the density function over banks, the promised rate of return and the total amount of money deposited in the bank to start the model going in period 0, $6K. Note that the expectation is taken over banks which is a random variable generated by the uncertainty in the banking system.

When played in extensive form, play takes place sequentially so that each agent has to decide period by period if he or she wants to remove his or her money. Here however, we can specify several different informational varieties. For example, the extensive form can be played such that after each period no information is given to the players as to how many people withdrew their money and therefore what they received if and when they did. This form is equivalent to the simultaneous form and we call it the Low-Information Sequential Form. Alternatively, we can specify a high-information version of the game in which after each period both the number of people who withdrew their money and the amount of money they received is revealed. This High-Information Sequential Form allows an expanded strategy space since here players can condition their withdrawal strategy both on how many people removed their money and what they received. In other words, history dependent strategies are available here.

## 3. Experimental Parameterization, Procedures and Design

To perform our bank run experiment groups of six subjects were recruited and asked to arrive at the experimental laboratory of the Center for Experimental Social Science at New York University. They were recruited from undergraduate economics classes at New York University. They were paid $5 for showing up on time and earned on average about $22 more in the 1.5 hour experiment.

Instructions were administered on their computer monitors. The instructions explained the problem and they were handed tables presenting their payoff function[3]. These tables told them what their payoff would be conditional on any scenario (or vector) of withdrawals and also conditional on each of the five banks their money might be in. It also listed their expected payoff for each scenario given the probability function defined over the banks. To test their knowledge of payoff table use, the instructions present them a series of quizzes to make sure they know how to use the payoff tables[4]. In addition, to help even more, subjects could use an on-screen "calculator" which was presented in a window on their screen if they clicked a button labeled "calculator". This calculator allowed them to enter any scenario of withdrawals into the computer and would tell them what expected payoff each hypothetical subject would get under that scenario. (Subjects used this calculator both before the first round of the experiment and during it. They also referred to their payoff tables repeatedly).

To perform our experiment we used several specific parameterizations of our model. More precisely, in the experiment, just as in our model, there are 5 potential banks and 6 agents. $r'$, the promised rate of return, is kept constant at 12% while the average rate of return $r^*$ (i.e. the rate of return of the mean bank $B_m$) varied from $r^* = .07$, to $r^* = .08$ and to $r^* = .14$. In addition, we ran the experiment under several informational conditions. Each combination of $r'$ and $r^*$ was run in the simultaneous or normal form and under the High and Low-Information Sequential forms. We also ran a set of experiments where information was asymmetrically distributed or where two of the six subjects were informed about the quality of the bank their money was deposited in before they had to make withdrawal decisions while four were uninformed. This was done using the $r^* = .08$ mean bank rate since with $r^* = .08$ the equilibrium to our symmetric information experiment is unique and we can make a clean measurement of the impact of asymmetric information. Finally, we ran a set of experiments where partial deposit insurance existed in an effort to compare the behavior of subjects with and without such insurance.

[3] Instructions and payoff tables are presented in the Appendix.
[4] Actually subjects became quite comfortable in using the payoff tables.

**Table 1: Experimental Design**

| Experiment | Form | Information | Rounds | Subjects | Equlibria |
|---|---|---|---|---|---|
| r*=7% | Simultaneous | NA | 21 | 48 (8 groups) | (6,0,0,0)<br>(0,6,0,0) |
| r*=14% | Simultaneous | NA | 21 | 30 (5 groups) | (0,0,6,0)<br>(0,0,0,6) |
| r*=7% | Sequential | Low, Symmetric | 21 | 42 (7 groups) | (6,0,0,0)<br>(0,6,0,0) |
| r*=7% | Sequential | High, Symmetric | 21 | 24 (4 groups) | (6,0,0,0)<br>(0,6,0,0) |
| r*=7%<br>(20% Insurance) | Sequential | High, Symmetric | 21 | 24 (4 groups) | (6,0,0,0)<br>(0,6,0,0) |
| r*=7%<br>(50% Insurance) | Sequential | High, Symmetric | 21 | 24 (4 groups) | (0,6,0,0) |
| r*=14% | Sequential | Low, Symmetric | 21 | 24 (4 groups) | (0,0,6,0)<br>(0,0,0,6) |
| r*=14% | Sequential | High, Symmetric | 21 | 24 (4 groups) | (0,0,6,0)<br>(0,0,0,6) |
| r*=8% | Sequential | High, Symmetric | 21 | 24 (4 groups) | (0,6,0,0) |
| r*=8% | Sequential | High, Asymmetric | 21 | 24 (4 groups) | NA+ |

+ Equilibria here are defined as functions and described in the paper.

Since our interests in this paper were both theoretical and policy oriented, we chose our parameters carefully. What we wanted were parameter values that would determine both an "early" and a "late" equilibrium. In the "early-equilibrium" experiment (r* = 0.07) subjects are faced with a greater risk of loosing their deposits if they remove their money too late since there was no bank that could pay all of the subjects their promised amount if they all chose to remove their funds in the same period. In addition, no matter what the pattern of withdrawals is, (even in equilibrium) there will always be some subjects (may be all) who will not be able to get his or her promised amount in the period they withdraw it. Hence the equilibrium in this treatment was for all subjects to either remove their money in period 1 or all to remove their money in period 2. In contrast, in the late-equilibrium experiment (r* = 0.14),

where all subjects either remove their money in period 3 or all remove their money in period 4, such risks were lessened since three out of five banks could pay the promised amount if all money was withdrawn at the same time (even in the last period). We wanted such "early" and 'late" equilibrium experiments since, for policy purposes, we wanted our bank insurance and informational interventions to be able to diminish the severity of bank runs by shifting withdrawals from early to late periods. This was accomplished by setting r* = 0.07 which as we see in Table 1, determines an equilibrium where either "everybody moves in Period 1" or "everybody moves in Period 2" and by setting for r* = .14 where either "everybody moves in Period 3" or "everybody moves in Period 4".

Finally we set r* = 0.8 for the incomplete information experiments since with r* = .08 the equilibrium to our symmetric information experiment is unique and we can make a clean comparison of the impact of insiders on withdrawal behavior by comparing the two treatments.

In our experimental design, while we run the bank-run experiment for 21 rounds we pay high stakes in the first round and low stakes in the remaining 20 rounds. More precisely, the first round is worth 20 times as much as any of the remaining rounds. We do this because bank runs, while important, are rather rare occurrences. In one's lifetime if one lived through one or two bank runs that would be considered many. As a result, while subjects may learn to reach an equilibrium after 20 rounds of play, in the real world people rarely have as much experience with bank runs. Therefore, we pay high stakes for the first round of the experiment and allow the remaining low stakes rounds to tell us something about learning.

We feel that this is an important feature of our design where we allow subjects to play for high stakes over a horizon that matches the one found in the real world yet lets them learn for low stakes later on in the experiment. Learning results are discussed in the Appendix.

## 4. Some Quick Theory

Since our experimental bank run game has discrete strategy sets and a finite number of players, we can search for all pure strategy equilibria by exhaustively checking all strategy combinations. The equilibria we find by doing this are presented in the far right hand column of Table 1[5].

As we can see from Table 1, our bank run model, with its present parameterization, yields equilibria that have certain distinct features. First, they involve all agents moving at exactly the same time (they are symmetric with respect to players). Second, if there are multiple equilibria, then they are adjacent i.e., either all remove their money in period 2 or all remove in period 3 or all remove their money in period 1 or all in period 2 etc. (This rules out multiple equilibria where, for example, either all people remove in period 1 or all remove in period 3). Third, as the mean rate in the industry, r* increases, agents remove their money later. So if one were to take r* as a cyclical indicator (average rate of return from investments in the economy when the bank crisis hits), we would expect money to be removed later in a bank run when it occurs during good times than during bad times (the run is less severe). Fourth, in our experimental parameterization, the equilibria for the Simultaneous form game remain the only pure strategy equilibria for both the Low and High-Information Sequential form games so we should not expect information to affect behavior in these experiments. Finally, although not indicated in Table 1, in our experiments when there is asymmetric information and where insiders exist, the expected length of time that money stays in the banking system in a separating equilibrium of the model increases, meaning that bank runs are less severe when insider information exists.

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[5] The program used to calculate these equilibria is available from the authors.

These results are summarized by the following propositions that will serve as the basis for the hypotheses we will test in Section 5.

**Proposition 1** ***Equilibrium Characterization:*** *The pure strategy equilibria to all versions of the bank run game tested in our experiments, involve all subjects removing their money at the same time.*

**Proof.** Since the strategy space for our game is finite, we can substantiate this characterization by enumerating all pure strategy configurations in all of our experimental parameterizations and exhaustively checking them for equilibria. Such a process confirms Proposition 1. ■

This proposition basically says that at any equilibrium of our experimental game, all subjects should remove their money at the same time. There are no asymmetric pure strategy equilibria in which subjects remove at different times.

To provide some intuition for Proposition 1, we start by noting that for any pair {r*,r'} there is a critical number c* such that the first c* people who remove their money in any period receive the promised amount in the period they withdraw. For the case where r* = .14 and r' =.12, c* = 5 and we will use this case to provide our intuition.

First, it should be clear that in any equilibrium there can be no gaps in withdrawal times (i.e. an equilibrium must be an "adjacent equilibrium" where either people withdraw their funds at the same or adjacent periods.) To illustrate this suppose n = $(n_1, n_2, n_3, n_4)$, is the vector of withdrawals ($n_t$ being the number of subjects withdrawing in period t) and suppose there is a gap, i.e., $(n_t, 0, n_{t+j})$ with $n_t$ and $n_{t+j} > 0$. Since $n_t \leq$ c* by construction, players who withdraw in period *t* get their promised return. Hence there is an incentive for one of them to deviate to the next period (move into the gap) remove their money later and get their promised return one period later after it has compounded for another period. Hence no gap can exist.
Next, there can be at most two adjacent periods in which people withdraw their funds. To demonstrate this, suppose this is not true. Let $(n_{t-1}, n_t, n_{t+1})$, be the number of subjects (greater than 0) who withdraw in period *t-1*, *t* and *t+1* respectively. We know (because c* = 5) that players who withdraw in period *t-1* and *t* get their promised returns. Therefore one of the players who withdraws in period *t-1* has an incentive to deviate to period *t* and get more.

Our next step is to show that subjects who move early in any adjacent equilibrium (if one exists) receive a higher payoff than those withdrawing later. To show this, again, suppose this is not true. Then one of the players who moves in period *t* would deviate to *t+1*. Now when he makes this deviation he brings with him his promised return of period *t* which is now allowed to compound one more period. By this deviation to period *t+1*, then, the subject gets a convex combination of what players in period *t+1* were getting and the promised of period *t* compounded one more period, which is greater that the promised of period *t*. Therefore any configuration where subjects in adjacent periods get more in period *t+1* than those in period *t* cannot be a candidate for an equilibrium.

Our final two steps are to show that if an adjacent equilibrium exists it must have 5 subjects withdrawing in period 3 and 1 in period 4 and then to show that even this is impossible.

To demonstrate the first assertion, say that we have an adjacent equilibrium where there is more than one subject withdrawing in period *t+1*. We know that players who move in period *t* receive more than those in period *t + 1*. We also know that since there are less than 5 of them, they are receiving their promised payoff. Hence one of the subjects who moves in period *t+1* would have an incentive to deviate to period *t* and get the promised payoff of period *t* which is greater than what he was getting in period *t+1*. So the only adjacent-equilibrium configurations must have 5 subjects removing first and 1 subject following in the next period. Hence, the only candidates for an equilibrium are the three vectors, $n^1$ = (5,1,0,0), $n^2$ = (0,5,1,0), $n^3$ = (0,0,5,1). $n^1$ and $n^2$ cannot be equilibria, however, since there is an incentive for the subject who removes his money alone to withdraw it later since that would allow him to get the same monetary payment but compounded for one or two more periods. So, the only candidate for adjacent equilibria is the vector $n^3$ = (0,0,5,1). From inspection of the payoff table, however, we can see that this cannot be an equilibrium since the subject who goes in period 4 gets an expected payoff of 11.23 while if he deviates to period 3 her expected payoff would be $13.34. Hence if an equilibrium were to exist in this game it must involve all subjects removing at the same time.

**Proposition 2** ***Comparative Statics:*** *For all parameter values of our experimental design, if we hold the promised rate of return by the banking industry constant, in equilibrium, money stays in the bank longer the higher the mean rate of return, r*, is in the banking industry.*

**Proof.** As with Proposition 1, since the strategy space for our game is finite, we can substantiate this result by enumerating all pure strategy configurations in all of our experimental parameterizations and exhaustively checking them for the appropriate comparative static results. See Table 1. ■

We can see these characteristics illustrated in Table 1. For instance, note that in the r'=.12, r*=.07 experiment subjects should, in equilibrium, remove their money relatively early (period 1 and 2) since the mean return in the banking industry is low, while in the r'=.12, r*=.14 experiments, subjects, in equilibrium, remove their money later (periods 3 and 4) since the banking industry, on average, is better. This means that bank runs should be less severe when a banking crisis develops in relative good times. Clearly, as the mean return in the banking industry, r*, increases, for any given r', it pays to keep your money in the banking system longer since, for any vector of withdrawals, the probability that the bank will be solvent at any time increases.

**Proposition 3** ***Informational Invariance:*** *For any configuration of r* and r', a withdrawal vector* $\alpha = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ *such that* $\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 6$*, is an equilibrium to either the High or Low- Information Sequential Form Game if and only if it is an equilibrium to the Simultaneous Form Game.*

**Proof.** See Appendix. ■

This proposition states that no new equilibria are introduced into the analysis when we move from the Simultaneous form to the extensive High-Information (or Low-Information) form of our laboratory bank run game. If a configuration is an equilibrium for the Simultaneous game it is also an equilibrium to the sequential form and visa versa.

**Proposition 4** ***Insider Information and Bank Run Severity:*** *Let $EL_{SI}$ and $EL_{AI}$ stand for the excepted length of time money remains in the banking system at any equilibrium of our bank run game with symmetric information (SI) and any separating equilibrium for the bank run game with asymmetric information (AI) where $r^* = .08$. Then, $EL_{AI} > EL_{SI}$.*

**Proof.** See Appendix. ■

This proposition implies that the presence of insiders is welfare improving since in any separating equilibrium of our bank run game with asymmetric information, money is withdrawn later than it is in the equilibrium to the same game without insiders or where information is symmetric.

## 5. Results

Our model and experimental design generate a number of hypotheses which we will investigate shortly. Some of these hypotheses come directly from the theory but some are behavioral and outside the predictions of the model. In our presentation we will mix our discussion of the predictions of the theory with the policy implications we see in the behavior of our subjects. To test our theory we will initially concentrate on behavior in the big-stakes first round of the experiment run with symmetric information (no insiders). We do this, as stated before, since bank runs are not events that occur often in one's life and hence we cannot look at long run convergent behavior as the basis upon which to make policy recommendations. Later we will comment on learning as well as discuss the results of our asymmetric information experiments.

### 5.1. Equilibria

We will phrase many of our hypotheses in terms of their consequences for the severity of bank runs since that is the focus of our paper.

**Hypothesis 1: Equilibria**

**The behavior observed by our subjects in the first round of the Simultaneous, Low and High Information treatments of our bank run experiment is consistent with the behavior predicted by the equilibria of the model.**

#### 5.1.1. Evidence:

Support for this hypothesis is mixed. In Figures 1a - 1f you see the histograms of the actions chosen by subjects in the first round of our bank run experiment in the Simultaneous, Low-Information Sequential and High-Information Sequential forms of the game for the r'= .12, r* = .07 (Figure 1a-1c) and r'= .12, r* = .14 (Figure 1d - 1f) treatments. In addition, Figures 1g-1i and 1j-1l presents the same data but aggregated into early, (periods 1 and 2) and late (periods 3 and 4) behavior. In the r* = .07 experiment, all early actions are equilibrium actions since they are consistent with some Nash equilibrium. The same is true for late actions in the r* = .14 experiment. We present these figures because with multiple equilibria it may be too much to ask that subjects solve the coordination implied by the theory in the first round of the experiment. However, we can check at least that they acted in accordance with some equilibrium. Hence all early actions in the r* = .07 experiment, we will call "equilibrium" actions, as we call all late actions in the r* = .14 experiment.

Note that if the predictions of the theory were substantiated we would see all observations either on periods 1 and 2 (r* = .07) or 3 and 4 (r* = .14) depending on the parameters of the treatment. This is basically true for the r'=.12, r* =0.14 case. Here, while subjects are supposed to remove their money late, in periods 3 and 4, we see that 73%, 75% and 92% actually do so in the Simultaneous, Low and High-Information Sequential treatments respectively. This behavior is quite close to that predicted by the theory especially when our subjects have not had a chance to learn the equilibrium. The same is not true, however, for the r'=.12, r* =0.7 experiment. While the theory predicts no late withdrawals in periods 3 and 4 we see that 50%, 67% and 58% of the subjects remove their money during these periods in the Simultaneous, Low and High-Information Sequential treatments respectively. Hence there appears to be a difference in behavior in these two cases.

### 5.2. Information:

Proposition 3 states that the equilibria of the bank run game for any configuration of parameters should be invariant to the form in which the game is played. Hence, we should not detect any difference in the behavior of subjects across experiments with the same parameters but different informational conditions.

**Hypothesis 2: Information**

**For any given set of parameters r' and r*, there is no difference in the play of our bank run game as informational treatments vary.**

#### 5.2.1. Evidence

This hypothesis is motivated by behavioral considerations and not theoretical ones. As Proposition 3 states, there should be no difference in the behavior of subjects when they

**Figure 1:** Actions Chosen in the First Round

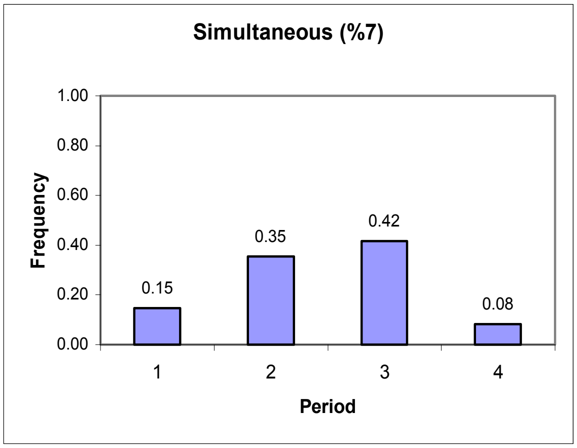


Figure 1a

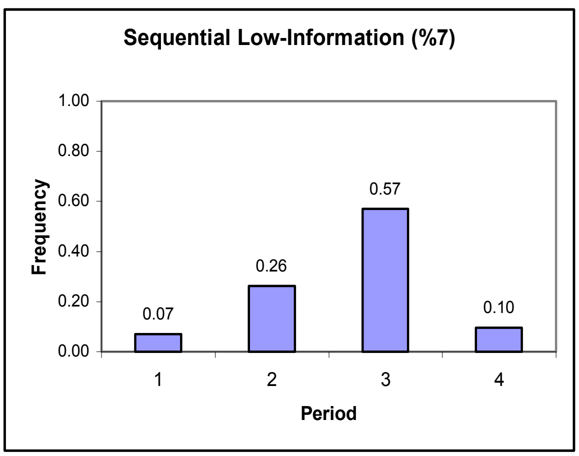


Figure 1b

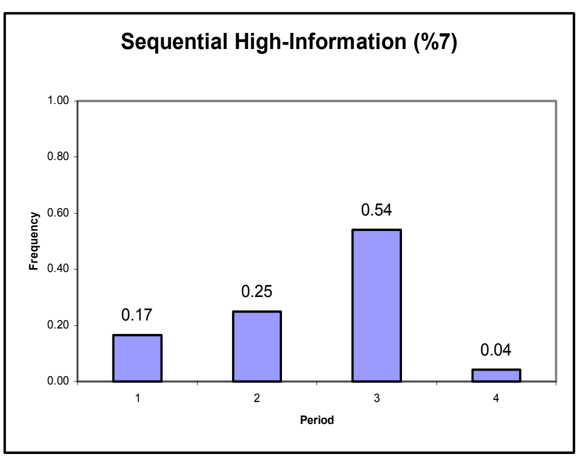


Figure 1c

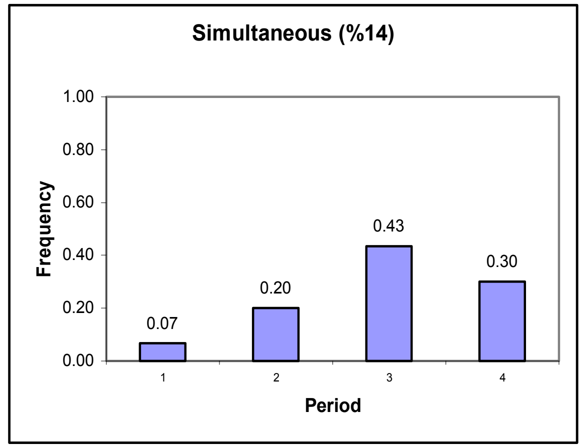


Figure 1d

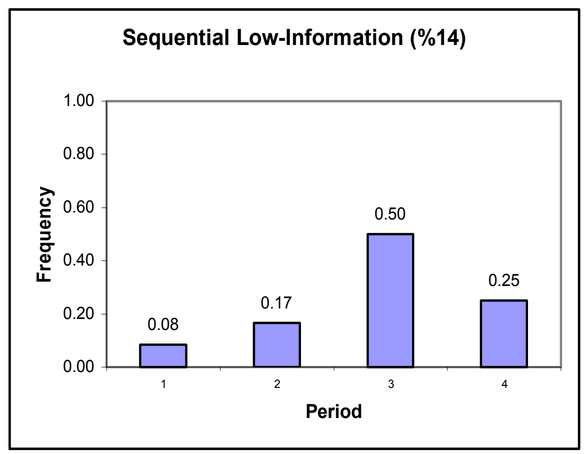


Figure 1e

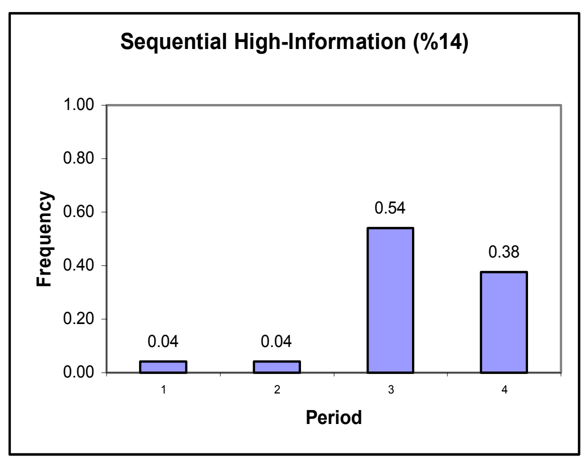


Figure 1f

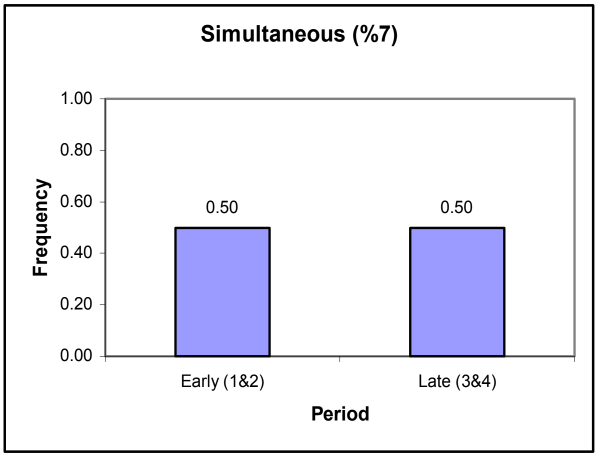


Figure 1g

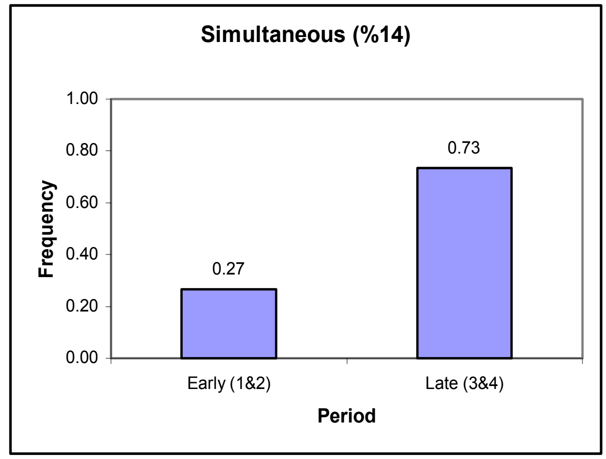


Figure 1j

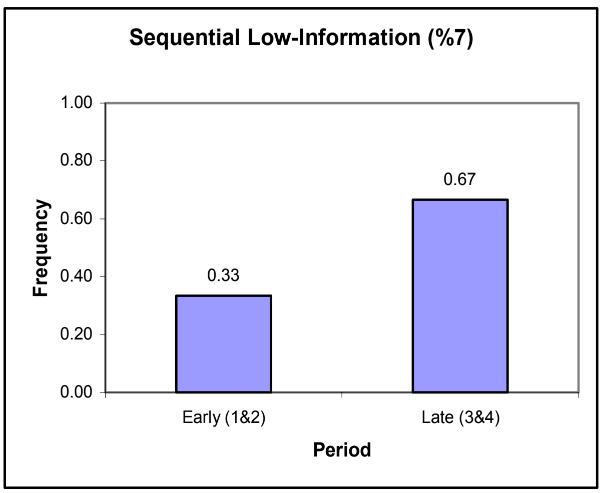


Figure 1h

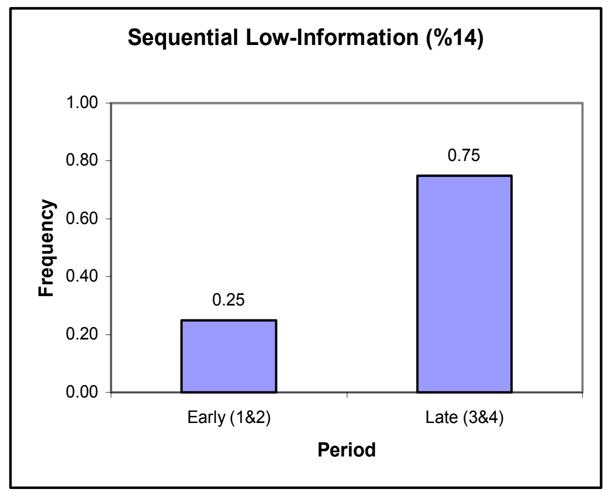


Figure 1k

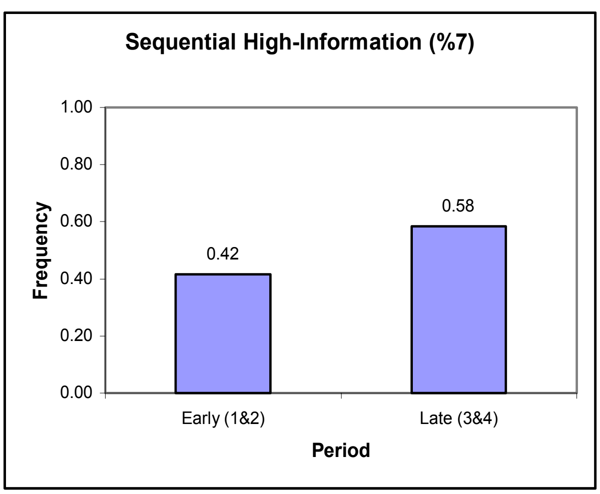


Figure 1i

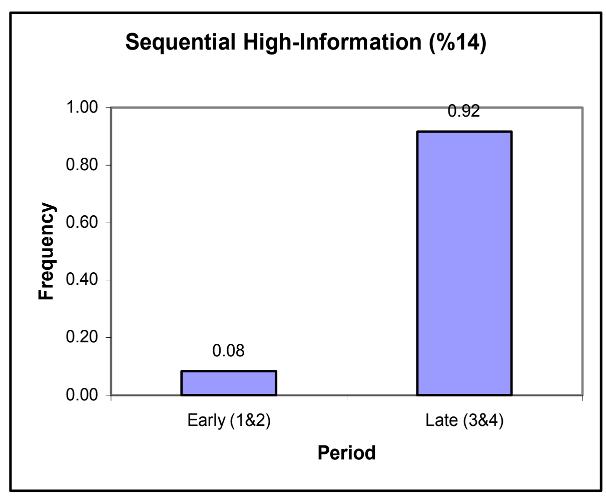


Figure 1l

play the Simultaneous game as opposed to the Low or High-Information Sequential Game. If a difference occurs, then we must ascribe it to extra-theoretical considerations.

### 5.2.1. Evidence

This hypothesis is motivated by behavioral considerations and not theoretical ones. As Proposition 3 states, there should be no difference in the behavior of subjects when they play the Simultaneous game as opposed to the Low or High-Information Sequential Game. If a difference occurs, then we must ascribe it to extra-theoretical considerations.

In the real world we view bank runs as occurring in a High-Information Sequential form. Basically you wake up one morning, read the papers, and realize that there is a financial crisis stirring. On your way to work, you see a line at the bank and later in the day you hear from your friends that they tried to withdraw their funds but could not. The next day you run to the bank and withdraw your money. In other words, we think that the most natural way to model bank runs is using the High Information Sequential form of the game. Therefore, if differences do occur as a result of informational treatments, then we would think that those derived from the High-Information Sequential play treatments have the greatest external validity. Consider Figures 1a-1l.

As we can see in our r* =.07, r' = .12 experiment there is no significant difference in the withdrawal behavior of our subjects across any of the informational treatments at, at least the 10% level. This is confirmed by a series of bilateral $\chi^2$ tests run on the early (periods 1-2) and late (periods 3-4) data[6].

The same cannot be said for the r* =.14, r' = .12 experiment, however. Here there seems to be a clear tendency for subjects to remove their money later when the bank run game is played in the High-Information Sequential form when compared to the Simultaneous form experiment. In fact, of the 24 subjects only 8% removed their money in period 1or period 2 in this experiment as compared to 27% and 25% for the Simultaneous and Low-Information Sequential forms of the game. These differences are significant at the 8% level using a $\chi^2$ test only for the comparison between the Simultaneous and Sequential High-Information form[7].

---

[6] Impact of information on Behavior for r*=7%:

| | **Seq. Low** | **Seq. High** |
|---|---|---|
| **Simul.** | $\chi^2 = 2.55$<br>p >.10 | $\chi^2 = 0.445$<br>p >.10 |
| **Seq. Low** | | $\chi^2 = 2.55$<br>p >.10 |

[7] Impact of information on Behavior for r*=14%

| | **Seq. Low** | **Seq. High** |
|---|---|---|
| **Simul.** | $\chi^2 = 0.019$<br>p >.10 | $\chi^2 = 2.97$<br>**p <.08** |
| **Seq. Low** | | $\chi^2 = 2.40$<br>p >.10 |

Bank runs appear to be less severe when subjects have more information about what other people have done. A logical consequence of this result is that wider dissemination of information about an evolving crisis may be helpful in slowing it down if people know in advance that they will have access to that information.

One reason why this may be true is that if people know that they will learn about the progress of a crisis as it proceeds, then they may decide to take a “wait and see” attitude and withdraw their money when they see the first bit of trouble. If everyone does this, then the crisis is less serve. Also, we know from other studies, see Schotter, Weigelt and Wilson (1994) and Cooper and Van Huyck (2001) that play of the same game in the normal and extensive form may not be equivalent because, perhaps, these two forms highlight different features of the decision problem.

### 5.3. Comparative Statics: Bank Run Severity and the Business Cycle

The comparative static results tested in our experiment provide an answer to a simple question: Are bank runs less severe when they occur in good as opposed to bad economic times? Put differently, should money remain in the banking system longer in the r* = .14, r' = .12 as opposed to the r* = .07, r' = .12 experiment? Our theory says yes since the equilibrium of the r* = .14, r' = .12 experiment suggest removal in periods 3 or 4 while in the r* = .07, r' = .12 experiment removal is earlier (period 1 or 2). This yields the following null hypothesis.

**Hypothesis 3: Comparative Statics**

**Under any information condition, subjects remove their money later in the r* = .14, r' = .12 experiment than they do in the r* = .07, r' = .12 experiment.**

**Evidence:**

Our data give mixed support for this hypothesis. Using a set of bilateral Wilcoxon tests to compare the mean withdrawal times in the first period of our r* = .07 and r* = .14 experiments, we find that there is a statistically significant difference in the withdrawal times of subjects between the r* = .07 and the r* = .14 experiments only when the game is played in the High-Information Sequential or Simultaneous versions ($z$ = -3.32, $p$ = 0.0005 in the Sequential High-Information r* = .07 vs .14 comparison and $z$ = -2.57, $p$ = .0052 for the Simultaneous r* = .07 vs .14 comparison). For some reason there was no significant difference when comparing the Sequential Low-Information experiments. More precisely, note that while in the High-Information Sequential r* = .14 treatment only 8% of the subjects remove their money in rounds 1 or 2 (early withdrawals) and 92% withdraw it in rounds 3 and 4 (late withdrawals), in the r* = .07 High-Information Sequential treatment these percentages are 42% and 58% respectively (see Figures 1i and 1l). In other words, there is a clear tendency to remove one's money later (less severe bank runs) when r* changes when the game is played in the High-Information Sequential Form. (Note that the fractions of early withdrawals is not that different when we compare the Sequential Low-Information r* = .07 and r* = .14 treatments, 33% vs 25%, respectively).

We find these results important from a theoretical and policy point of view. First, theoretically we should detect differences between the behavior of our subjects as we vary r*. The fact that the theory predicts behavior best in the High-Information Sequential version of the experiment is important since we consider that most empirically relevant form of the game. From a policy point of view this result implies that during the course of a bank run it is better, rather than worse, to offer information as to how people are doing when they withdraw their money as long as people know that they will have access to this information as it is revealed.

## 5.4. Deposit Insurance

As stated before, we are interested in the type of intervention that can dampen bank runs. While full insurance is almost certain to do so, it can be quite costly and can create moral hazard on the part of the banks since depositors feel no obligation to monitor how their bank runs its affairs[8].

In our deposit insurance experiments we imposed a 50% and a 20% insurance rate in two experiments so that no subject could lose more than 50% or 80% respectively, of what was owed them. We imposed this on the r* = .07, r'= .12 experiment since it is in that experiment that subjects were most at risk and were supposed to remove their money early as opposed to late. We also used the High-Information Sequential version of the experiment since, as we have said before, we consider that one to be the most empirically relevant.

**Table 2:** Withdrawal Times with and without Insurance

| | **Period** | | | |
|---|---|---|---|---|
| **Experiment** | **1** | **2** | **3** | **4** |
| No Insurance | .17 | .25 | .54 | .04 |
| 20% Insurance | .04 | .21 | .67 | .08 |
| 50% Insurance | .00 | .17 | .75 | .08 |

We find, using a simple linear regression model, that withdrawal times are positively related to the level of deposit insurance, although the distribution of withdrawal times differs from the no-insurance treatment only for the 50% case. To demonstrate this we present Table 2 and Figure 2.

Note that in Table 2 while 42% of subjects remove their money early (period 1 or 2) the experiment with no insurance, only 25% and 17% of the subjects removed their money in these rounds in the 20% and 50% insurance experiments, respectively. These differences,

[8] Bhattacharya, Boot and Thakor (1998) is a comprehensive survey on bank regulation that discusses the alternatives for full deposit insurance.

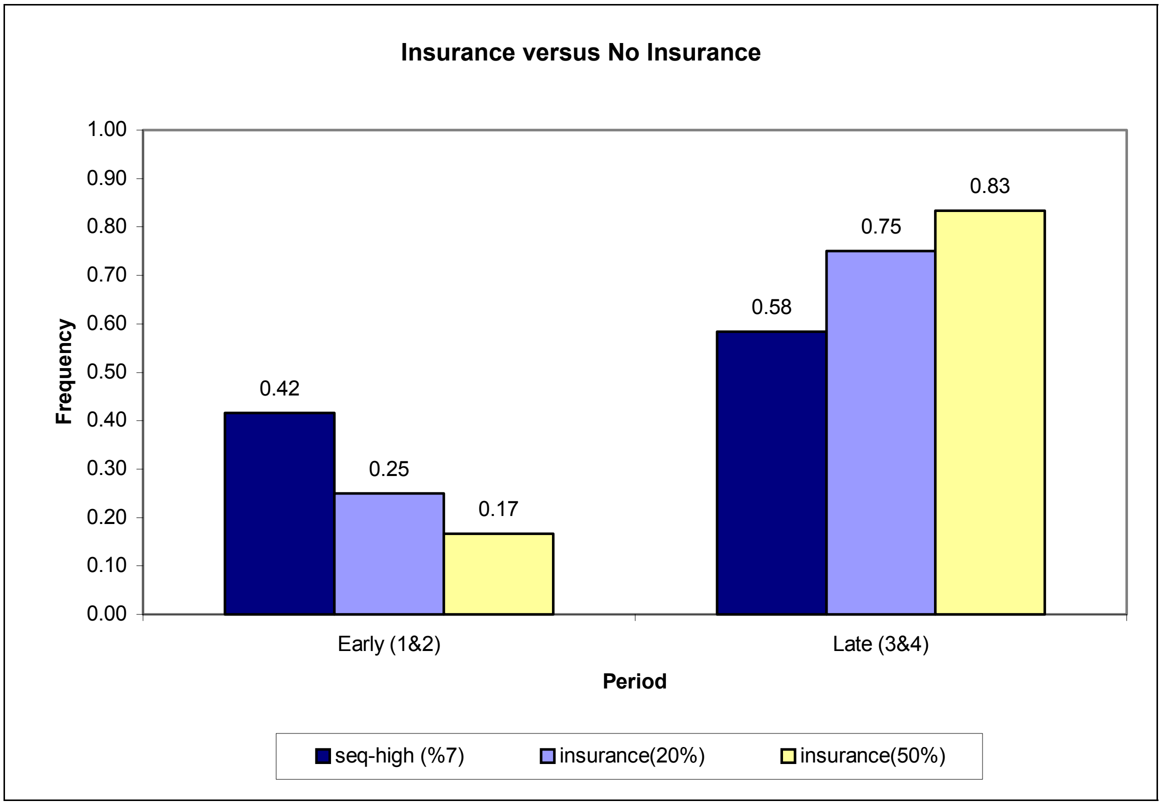


Figure 2: Effect of different levels of insurance on withdrawal times.

between insurance treatment and non-insurance treatments, are statistically significant at the 5% using a $\chi^2$ test for the comparison between the early-late data of the no-insurance and the 50% insurance treatment only ($\chi^2$ = 3.63, p ≈ 0.05). It appears as if 20% insurance is too small to affect behavior, however. Note also that issuing 50% insurance totally eliminates period 1 withdrawals.

When we run a simple OLS regression of the withdrawal period on the percentage of insurance (0%, 20% or 50%) for the first-round data pooled across all of the experiments where r' = 0.12 and r* = 0.07, we find that insurance has a positive and significant impact on the withdrawal time[9]. In other words, as we increase the level of insurance in our experiments subjects tend to withdraw their money later and later.

These results and those discussed above lend support to the view that full (100%) deposit insurance is not necessary to dampen bank runs and hence may be inefficient.

[9] Impact of Insurance on Withdrawal Times

| | **Coefficient** | **Std. Error** | **z** | **p** |
|---|---|---|---|---|
| **constant** | 2.549 | .124 | 20.50 | .000 |
| **insurance** | .800 | .400 | 2.00 | .049 |

n = 72, $R^2$=.054

## 5.5. Asymmetric Information

Probably our most interesting results are derived from our asymmetric information experiments. In these experiments, as discussed above, we informed two subjects before each round about the identity of the bank their money was invested in, while the other four received no information. Hence, in each round there were two informed and four uninformed subjects with the same two people always functioning as the informed subjects. Each round the bank was drawn randomly in an *iid* fashion.

While there are many possible separating equilibria for this model in which the informed subjects move first knowing which bank their money is invested in and then the uninformed, seeing what the informed have done, move later, they all share one important property which is that all separating equilibria are welfare improving when compared to the (unique) equilibrium of our r* = .08, r' = .12 bank run game played with symmetric information (where everyone is uninformed). This is equivalent to saying that in any separating equilibrium of the asymmetric information game, on average, money stays longer in the bank. (Remember, when r* = .08 and r' = .12, all subjects remove their money in period 2 (see Table 1)). The reason here is that since the strategies of the uninformed are conditional on the actions of the informed, and since the informed know this and it is in everyone's interest to keep their money in the bank as long as possible, the informed are able to wait to withdraw their money even when they know that the bank is a bad one. The uninformed, in equilibrium, are willing to wait since they get more money, on average, by removing their money later even if it is after the two informed subjects remove theirs.

We are interested in several aspects of this asymmetric information game. First, we are interested in finding out if it is true that welfare increases in the presence of asymmetric information. Second, we are interested in seeing if people follow a separating equilibrium in that the uninformed wait until the informed remove their money and the removal times of the informed basically are consistent with some separating equilibrium.

**Withdrawal times**

Figure 3 presents the histograms of first round removal times for our Asymmetric Information and the Symmetric Information, r* =8, r' =.12 experiments.

Note that the most dramatic difference between the two experiments in the difference is the frequency of period 4 withdrawal times with 21% more withdrawals in the asymmetric experiment. On average, money remained in the bank longer in the asymmetric information experiment than in the associated symmetric information no-insider experiment. For example, on average, across all sets of experiments using r* = .08 and r’ = .12, in the first round money stayed in the bank, on average, for 2.83 periods in the no-insider experiments while it stayed there for 3.25 periods in the asymmetric-information experiments. A Wilcoxon test run to test the hypothesis that these withdrawal times came from the same population against the one sided alternative that money is

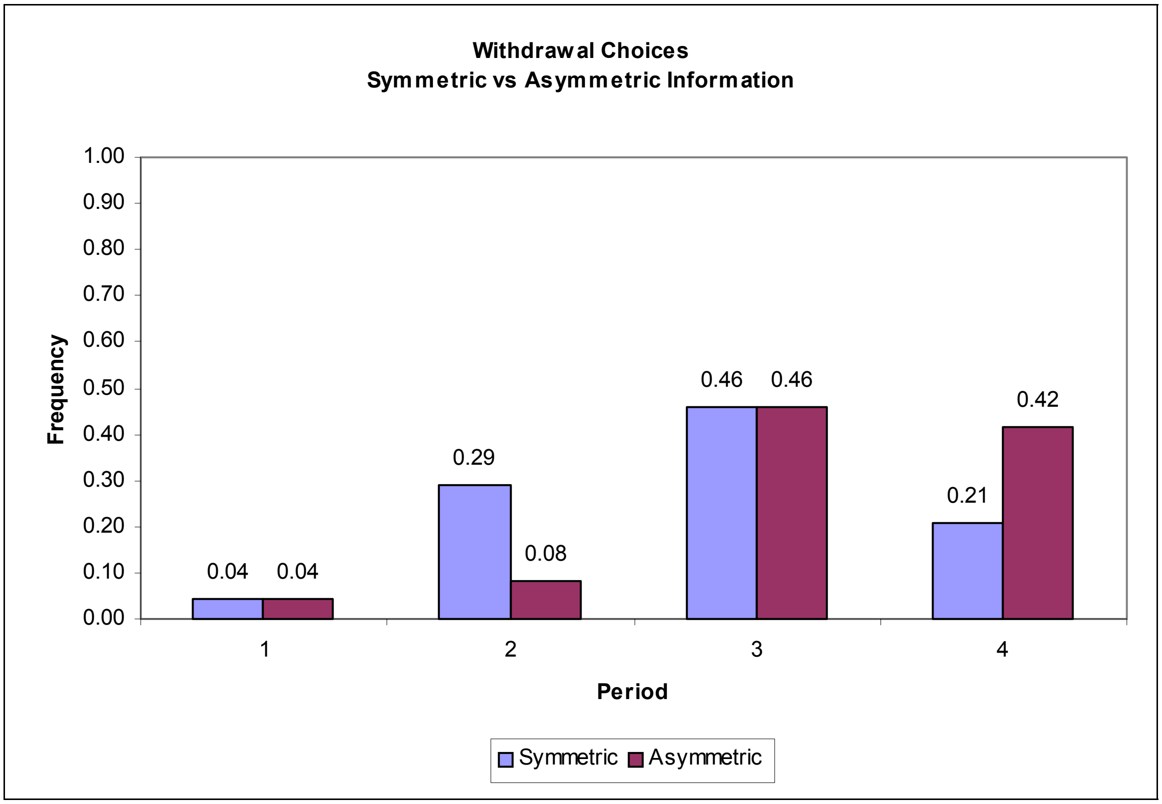


Figure 3: Withdrawal Choices, Symmetric vs Asymmetric Information

withdrawn later in the asymmetric-information experiment, rejects the null at the 3% level of significance ($z$ = -1.871, $p$ = 0.030). An important feature of the experiments with insiders is that for better banks, on average, money stayed longer in the banking system. Therefore, with asymmetric information, runs were more severe when the chosen bank was not performing well, that is, runs were correct runs on average. We can see this if we look at the average time money stayed in the bank for the data pooled over the 21 rounds.[10,11]

## Withdrawal Strategies

We are interested in knowing if subjects followed a separating equilibrium in this experiment. Such equilibria have a number of characteristics. Most importantly, informed

[10] Average time money stayed in the bank for each bank in the asymmetric information experiments.

| | Average |
|---|---|
| Bank 1 | 2.73 |
| Bank 2 | 2.85 |
| Bank 3 | 3.02 |
| Bank 4 | 3.11 |
| Bank 5 | 3.23 |

[11] Saunders and Wilson (1996) discuss the role of informed depositors in the bank runs during the Great Depression.

agents should make their withdrawal choices by conditioning on the bank. Second, uninformed subjects should make their withdrawal choice by conditioning on the actions of the informed.

Confirming that informed subjects followed a separating equilibrium involves estimating their strategy functions. For example, we are interested in the withdrawal times of informed subjects conditional on the bank announced to them in any round of the experiment. To estimate this relationship we ran a set of multinomial logit regressions - one for each subject. In these regressions the dependent variable was a discrete variable taking on values of 1,2,3 or 4 depending on the period in which money was withdrawn. The right hand side, independent variable, was simply the bank rate realized in that period.

While the bank rate variable was only significant in about half of our subject regressions, all the signs were positive indicating a positive relationship existed. Of course with only 21 observations per subject and discrete right-hand and left-hand variables we are not surprised that a number of the coefficients were not significant.

When our multinomial logit regression is run on the pooled data from all informed subjects, however, we find a highly significant and positive coefficient for the bank rate variable indicating a positive relationship between the bank rate and the probability of removing money later[12].

Perhaps a more direct way to show that informed subjects followed a separating equilibrium can be seen in Figure 4. This figure shows, for any realized bank, the withdrawal times of informed subjects. All observations are pooled over all informed subjects and over the entire length of the experiment.

If a separating equilibrium were evident in the data, then for informed subjects, we should expect to see the distributions of withdrawal times shift as the realized bank gets better and better. (We actually expect it to shift to the right). The mean withdrawal times should also increase. As we see in Figure 4 this is in fact the case. For example, the modal withdrawal time is period 2 when the bank is Bank 1, period 3 when it is Bank 2 or 3, and period 4 when it is Bank 4 or 5. Further, using a Wilcoxon test we can reject the hypothesis that withdrawal times were identical for any pair of adjacent banks. More

[12] Multinomial Logit Results for Withdrawal Behavior of Informed Subjects

| Period** | Coefficient* | Std. Error | z | p |
|---|---|---|---|---|
| 2 | .6412 | .2377 | 2.70 | .007 |
| 3 | .7932 | .2366 | 3.35 | .001 |
| 4 | .8286 | .2365 | 3.50 | .000 |

n = 168, Pseudo $R^2$=.2810, Log Likelihood = -167.44
* Coefficients indicate the impact of an increase in the bank rate on the probability of withdrawal in any given period.
** Period 1 is the comparison period.

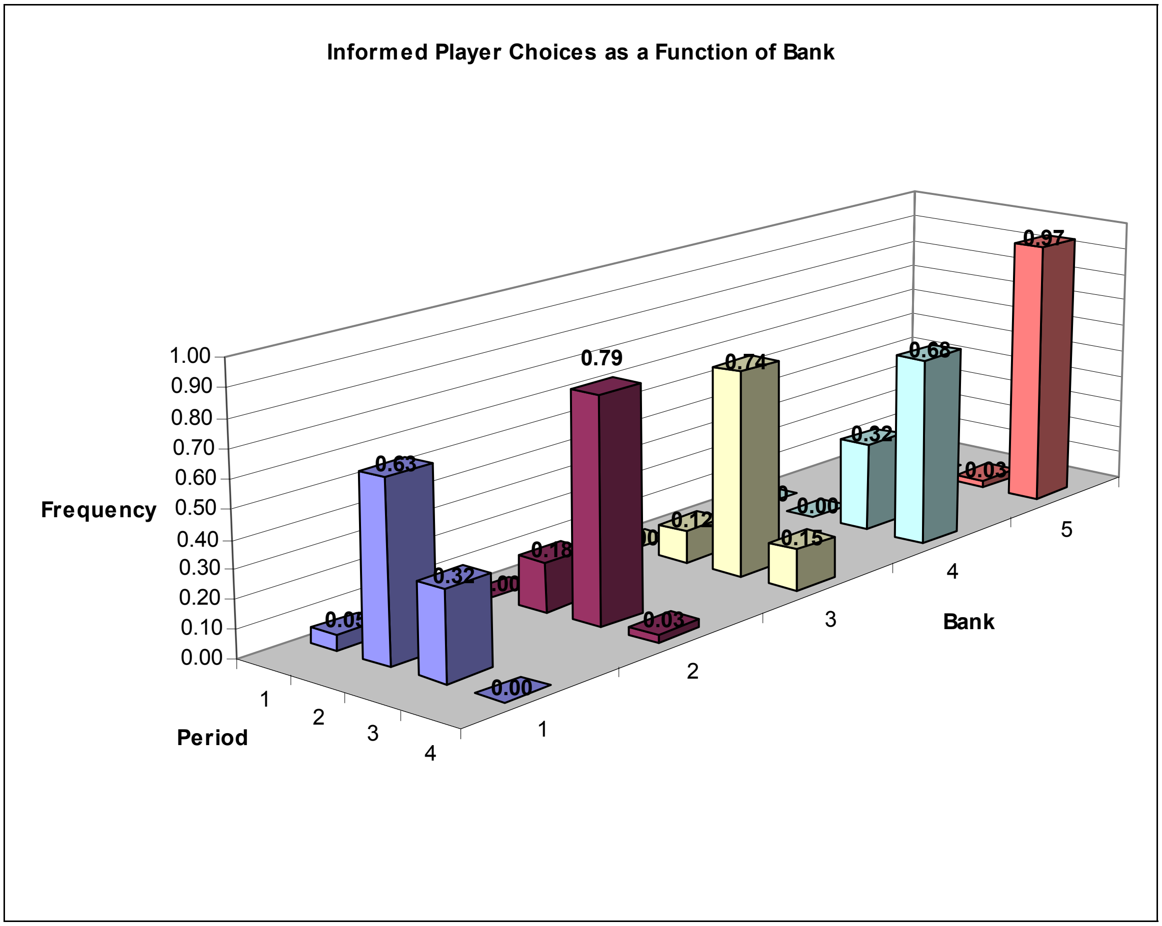


Figure 4: Informed players' choice as function of bank.

precisely, a set of binary Wilcoxon tests[13], testing for equality of mean withdrawal times rejects the hypothesis that these times are equal for comparisons of Bank 1 vs Bank 2, Bank 3 vs Bank 4 and Bank 4 vs Bank 5 at at least the 1% level in favor of the one tailed alternative that subjects withdrew later the better the bank. (For Bank 2 vs Bank 3 the difference is significant at the 7% level). Further, calling banks 3, 4 and 5 good banks and banks 1 and 2 bad banks we can easily reject the hypothesis of equality of mean withdrawal times across these categories in favor of the one-tailed alternative that informed subjects withdrew their money later when good banks were realized ($z = -8.5786$, $p \approx 0$). Finally, note that when Bank 5 is announced informed subjects remove their money in period 4, 97% of the time and do so 68% of the time when Bank 4 is announced. No informed subject removes her money in period 4 when Bank 1 is announced.

[13] One-tailed Wilcoxon test results:

| | z | p |
|---|---|---|
| Bank 1 vs 2 | -4.7603 | .0 |
| Bank 2 vs 3 | -1.4649 | .07 |
| Bank 3 vs 4 | -4.3406 | .0 |
| Bank 4 vs 5 | -3.0749 | .0005 |

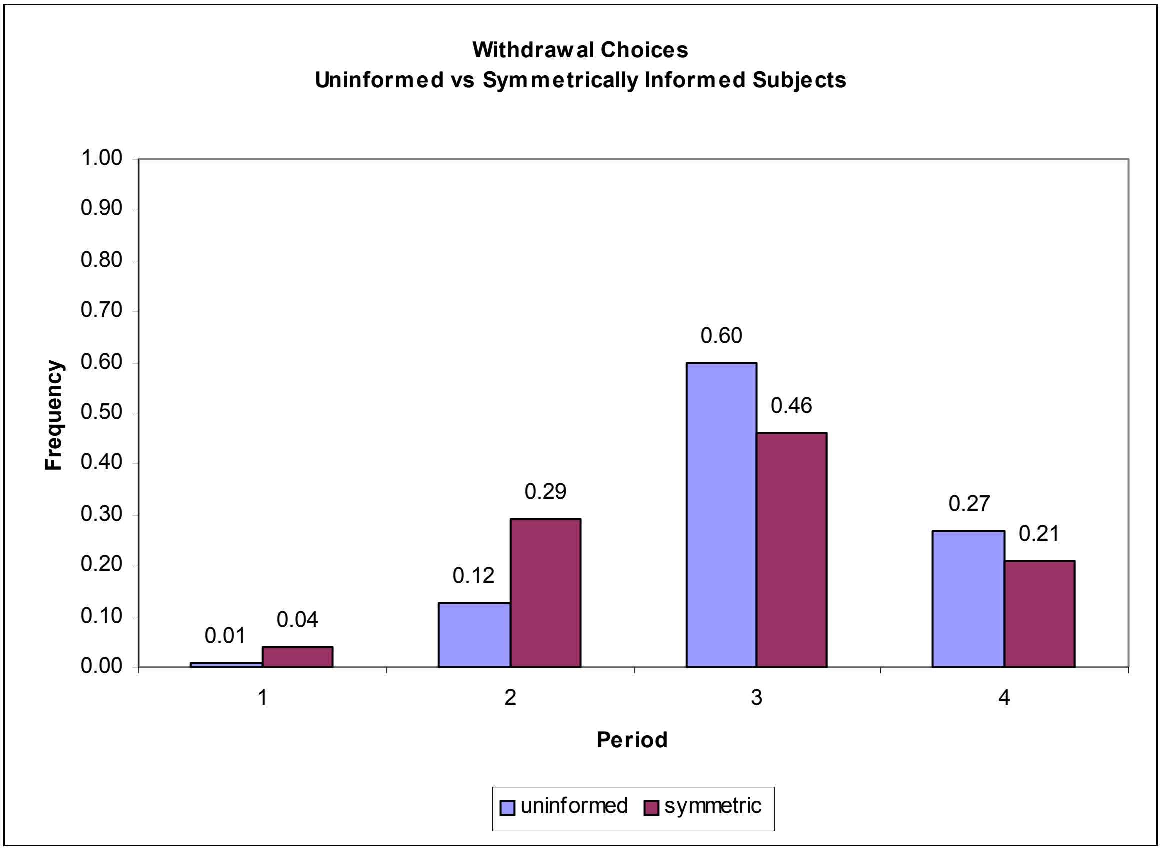


Figure 5: Withdrawal Choices Uninformed and Symmetrically Informed Subjects

With respect to the uninformed subjects, we support the hypothesis that these subjects were engaged in separating equilibrium-like behavior by showing that their behavior changed when they were in the presence of informed subjects in comparison to how they behaved in our symmetrically informed r' = .12 r* = .08 experiment where, in essence all subjects were uninformed. We would expect that in the asymmetric information experiment they would condition their withdrawal on the behavior of informed subjects and hence withdraw later. To illustrate that this is the case consider Figure 5 which presents the histograms of withdrawal times for all uninformed subjects in our asymmetric information experiment and all subjects in our symmetric r' = .12 r* = .08 experiment.

As we see, it is clear that uninformed subjects in our asymmetric information experiment withdraw their money later than those in the comparison symmetric information experiment. For example, while 87% of the subjects withdraw in period 3 and 4 in the asymmetric information experiment, only 67% of the symmetrically informed subjects do. A Wilcoxon test rejects the hypothesis of equality between the samples in favor of the one-tailed alternative that the mean withdrawal time of the uninformed subjects in the asymmetric information experiment is greater than the mean withdrawal time in the symmetric information experiments at the .0004 level ($z = 3.514$, $p \approx 0.0004$).

Perhaps a more direct way to make the point that uninformed subjects conditioned their withdrawal behavior on the actions of the informed is to use a counting metric. The idea behind this approach is that in any separating equilibrium no uninformed subject is ever expected to remove his or her money without seeing someone else remove theirs first. Using this fact we count the number of times that uninformed subjects withdrew their money before any one else did as opposed to waiting for at least one other person to do so. Whenever an uninformed subject was **not** the first to withdraw his or her money (i.e. if he or she withdrew at least one period after someone else) we counted that observation as supporting the separating equilibrium while any time an uniformed subject removed his money without anyone having done so in previous periods, we counted that as evidence against the separating equilibrium hypothesis.

Using this approach we found that of the 356 removal decisions pooled over all experiments and all subjects, 215 were supportive of the separating equilibrium while 141 contradicted it. Using a binomial test we tested the null hypothesis that the removal times of uninformed were random (equally likely to be before or after someone else) against the hypothesis that uninformed subjects were more likely to remove their money after the informed (or at least after someone else had removed theirs). We were able to reject the null at the 1% level of significance ($z = 5.88$, $p < 0.001$).

Our final attempt to convince you that subject behavior in our asymmetric information experiments had the earmarks of a separating equilibrium comes a set of questionnaires we administered asking our subjects to describe their behavior in the experiment by writing down what type of strategies employed. From their responses it was clear that both the uninformed and the informed tended to use separating equilibrium-type strategies. Some of these reports can be found in the Appendix.

In summation, it appears as if the behavior of our subjects in the asymmetric information experiments we ran was consistent with the behavior of subjects following some type of separating equilibrium. Informed subjects clearly conditioned their withdrawals on the bank drawn while uninformed subjects appeared to wait longer before withdrawing implying they were conditioning their withdrawal choice on the behavior of informed subjects. These stylized facts were supported by comments made by our subjects in post-experiment questionnaires.

## 6. Learning

As stated before, we do not consider learning a relevant subject for bank run experiments since few of us will ever have repeated experience with them in our lifetimes. One bank run or perhaps two may be all that anyone is likely to experience. However, we did run our experiments 21 times in an effort to see if the equilibrium predictions of our model had drawing power. Table 3 compares the withdrawal times of our subjects over the first and last five rounds of each experiment.

As you can see, the results of this comparison are mixed. Subjects in the $r^* = 0.14$ experiment do change their behavior over the 21 rounds when we compare their actions in the first and last 5 rounds. Here there is a clear tendency to move toward the equilibrium predictions and withdraw later in periods 3 or 4. These differences are significant using a Wilcoxon test and testing the null hypothesis of no change against the alternative of change in the direction of the equilibrium predictions (which in this case is to have the withdrawal times move later in the last five rounds). In the r* = 0.07 experiments we can only reject the null hypothesis of no change in the Sequential Low-Information treatment. These same tests indicate that withdrawal times are closer to the equilibrium withdrawal times for the 20% and 50% insurance experiments as well but there is no change in the r* = 0.08 and Asymmetric Information experiments.

In short, it appears as if the feedback we gave subjects in this experiment was not sufficient to lead them to equilibrium behavior in a very consistent manner. Still, by and large there was a movement in the right direction.

**Table 3: Frequencies of Withdrawal Choices in the First and Last 5 Rounds**

| | Rounds | Period 1 | Period 2 | Period 3 | Period 4 |
|---|---|---|---|---|---|
| Simultaneous (7%) | First 5 | 0.08 | 0.42 | 0.43 | 0.07 |
| | Last 5 | 0.18 | 0.32 | 0.44 | 0.07 |
| Sequential-Low (7%) | First 5 | 0.10 | 0.35 | 0.41 | 0.14 |
| ($z$ =1.8, $p$ = 0.04) | Last 5 | 0.06 | 0.51 | 0.36 | 0.07 |
| Sequential-High (7%) | First 5 | 0.11 | 0.36 | 0.43 | 0.10 |
| | Last 5 | 0.04 | 0.37 | 0.50 | 0.09 |
| Insurance 20% | First 5 | 0.04 | 0.27 | 0.50 | 0.19 |
| ($z$ = 2.6, $p$ = 0.005) | Last 5 | 0.03 | 0.43 | 0.45 | 0.09 |
| Insurance 50% | First 5 | 0.06 | 0.29 | 0.48 | 0.17 |
| | Last 5 | 0.03 | 0.45 | 0.43 | 0.10 |
| Simultaneous (14%) | First 5 | 0.02 | 0.17 | 0.39 | 0.42 |
| ($z$ =-3.73, $p$ = 0.0001) | Last 5 | 0.00 | 0.00 | 0.43 | 0.58 |
| Sequential-Low (14%) | First 5 | 0.04 | 0.23 | 0.38 | 0.35 |
| ($z$ = -2.52, $p$ = 0.006) | Last 5 | 0.02 | 0.05 | 0.52 | 0.41 |
| Sequential-High (14%) | First 5 | 0.04 | 0.11 | 0.48 | 0.38 |
| ($z$ = -3.61, $p$ = 0.0002) | Last 5 | 0.01 | 0.03 | 0.39 | 0.58 |
| Sequential-High (8%) | First 5 | 0.04 | 0.24 | 0.57 | 0.15 |
| | Last 5 | 0.01 | 0.22 | 0.72 | 0.06 |
| Asymmetric | First 5 | 0.03 | 0.08 | 0.55 | 0.33 |
| | Last 5 | 0.01 | 0.07 | 0.41 | 0.41 |

## 7. Conclusion

This paper has tried to investigate the factors that determine the severity of bank runs and to point out possible policies that might help dampen them. We have demonstrated that in general the more information economic agents can expect to have about an ongoing crisis, i.e. the more they can expect to learn about the crisis as it develops, the more willing they are to restrain themselves in withdrawing their funds from banks once a crisis actually occurs. In addition, we have seen that deposit insurance, even of a limited type, can also help to diminish the severity of bank runs. This is important because full deposit insurance creates moral hazard on the part of bank managers since their actions tend not to be monitored by depositors if their funds are fully insured. By offering only partial insurance, the hope is that not only will bank runs be less severe, but depositors will also be more vigilant in their monitoring of bank managers. Finally, we have seen that the presence of insiders who know the quality of the bank their money is invested in, is welfare increasing in the sense that when such insiders exist, subjects tend to withdraw their money later than they would if no such insiders exist.

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# 8. Appendix

## 8.1. Proof of Proposition 3:

The proposition is true trivially for the Low-Information Sequential case since the information structures of the two game-forms are identical.

In the High-Information Sequential case we have proven that the only pure strategy equilibria for our bank run game are the symmetric pure strategy equilibria in which all subjects remove their money at the same time. Now consider an allocation, $\alpha = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ of players to removal times in the sequential version that is not an equilibrium in the simultaneous version, where $\alpha_t$ are the number of players who remove their money in period *t* under allocation $\alpha$. If this allocation were made in the simultaneous game, we know, by assumption, that at least one player would have an incentive to deviate. Let us look at the best response function for players in the Simultaneous version when they face allocation $\alpha$.

In the Simultaneous version, players calculate a best response under the assumption that no other player will change his or her removal time so that they can take the actions of the other n-1 players as fixed. We cannot necessarily make this same ceteris paribus assumption in the sequential version since if a player decides not to move according to $\alpha$ but to remove his or her money later, this lack of action will be detected by other players and they may change their actions in response. Hence, such deviating players cannot carry out their best response to $\alpha$ under the assumption that the other n-1 players will stay fixed in their removal times. But that is only the case when a player decides to move later than prescribed by $\alpha$. If their simultaneous version best response is to move earlier, then they can execute that best response in the sequential form game as well since, while their deviation will be detected, it will be too late for other players to do anything about it since the deviating player will already have her money. Such deviators can maintain the same ceteris paribus assumption about the other n-1 players as players in the simultaneous form game. Hence, any deviation from $\alpha$ in the simultaneous form game which suggests that players remove their money earlier can be executed in the sequential form game without being detected and hence will be done. (The same logic applies to players in period 3 who want to remove their money later since while the players who remove their money in period 4 will notice it, they cannot remove their money until the next period and that is too late). So if $\alpha$ is not an equilibrium in the Simultaneous version it will not be an equilibrium for the sequential form game as long as the best response to $\alpha$ in the simultaneous game requires people in any period to remove their money earlier or a period 3 player to remove later. So we only need to consider deviations for subjects who, under configuration $\alpha$, are supposed to withdraw their money in periods 1 or 2 but are contemplating a deviation.

The key question, then, is what conjecture will players who are supposed to move in periods 1 and 2 make about the reactions of the other, later-moving players, when they deviate and do not withdraw when they are expected to. To prove our result, we will make the worst possible conjecture from their point of view which is that if they fail to withdraw when they are expected to, all of the other players will immediately withdraw their money in the very next period. Hence, if configuration α calls for a player to remove his or her money in period 1 and he or she does not do so, we will assume that all of the remaining players (who were called on to remove after period 1) will withdraw in period 2. If it is still worthwhile for the period-1 player to deviate under these circumstances (or for a later moving player to move earlier if the period-1 mover has no incentive to move later), then we know that such a configuration is not an equilibrium.

From inspection of the payoff table for r* = .07, r' = .12 (a similar argument can be made for the r* = .14, r' = .12' case as well), we can see that for any configuration, α, where 3 or fewer players are expected to remove in period 1, any one of them would have an incentive to deviate to period 2 even under our pessimistic assumption. (They may have even better deviations under alternative assumptions but that fact is not needed in our argument). Hence such a configuration cannot be an equilibrium.

When four or more subjects are expected to withdraw in period 1, then for any configuration of later-moving subjects, at least one of them would want to move earlier. Hence, no configuration in which some, but not all, subjects move in period 1 can be an equilibrium to the High-Information Sequential form game.

Finally, let's look at the case where no subject removes in period 1 but one or more in period 2. Here, we look at configurations in which the earliest a subject is supposed to move is period 2. However, the same argument will establish the result here as well.

## 8.2. Proof of Proposition 4:

The proof uses certain domination relationships concerning the payoffs to informed subjects to calculate the minimum expected number of periods money will remain in the bank during any separating equilibrium. Since we know that when information is symmetric all subjects withdraw their funds in period 2, if the minimum we calculate is greater than 2 periods, we have proven our result.

We start by showing that if the bank chosen is Bank 3, in any separating equilibrium no informed subject will withdraw in period 1. To show this assume that a separating equilibrium did in fact exist where, conditional on Bank 3, all informed subjects move in period 1. In addition, assume that such an equilibrium directs the four uninformed subjects to move in period 2. Therefore in this equilibrium we would have the 2 informed subjects moving in period 1 and the 4 uninformed subjects moving right after them in period 2. In this equilibrium the two informed subjects earn 11.2. However, if either of them decided to deviate and withdraw in period 2, they would earn 11.58. They will earn even more if the uninformed had decided to remove their money later. Therefore, assuming that the uninformed move in period 2 is the worst case for the informed subjects given their period 1 move and hence if they find it beneficial to deviate here they will do so under other assumptions. So no separating equilibrium can have informed subjects removing their money in period 1 conditional on knowing the bank is Bank 3. They must withdraw in period 2 or later.

Further, if the bank chosen is Bank 5, it is a dominant strategy for the informed subjects to wait until Period 4. So we have established that in any separating equilibrium when the bank is Bank 3 the withdrawal period cannot be earlier than period 2 while if it is Bank 5 it is dominant to wait until period 4.

Given these facts consider the following proposed strategy pair which has the property that, if it were to actually be an equilibrium, it would be that one with the shortest withdrawal time that respects the two properties we have mentioned above.

**Informed:** If Bank 1 or Bank 2, withdraw in Period 1. If Bank 3 or Bank 4, withdraw in Period 2. If Bank 5, withdraw in Period 4.

**Uninformed:** Do not remove money in Period 1. (Since this strategy (removing in period 1) is not conditioned on the behavior of an informed subject, it can never be part of a separating equilibrium). If somebody removes in Period 1, remove in Period 2. If somebody removes in Period 2, remove in Period 3. Otherwise remove in Period 4.

In this worst case scenario, as we see in the table below, the expected length of time money remains in the banking system is 2.11 periods (which is greater than the 2 periods it remains in the system when information is symmetric).

| | |
|---|---|
| **Bank 1** | (2(1)+4(2)) / 6 =5/3 |
| **Bank 2** | (2(1)+4(2)) / 6 =5/3 |
| **Bank 3** | (2(2)+4(3)) / 6 =5/3 |
| **Bank 4** | (2(2)+4(3)) / 6 =5/3 |
| **Bank 5** | 4 |
| **Average** | 2.11 |

## 8.3. Student Reports

For example, consider the following two statements from the two informed subjects who engaged in our experiment on July 25, 2002 and described their behavior as follows:

**Player 1 (Informed)**

*If it was Bank 1, I withdrew in period 2.*
*Bank 2: Period 2 or 3 (depending on how many withdrew before me).*
*Bank 3: Always period 3.*
*Bank 4 & Bank 5: Always period 4.*

**Player 4 (Informed)**

*After observing that no one withdrew ever during the first time period, I withdrew in the 2nd time period for Bank 1. For Bank 3 or 4, I withdrew in the 3rd time period (only when it was Bank 1, did anyone withdraw before the third period - I assume it was me and the other informed player). For Bank 5, I left the money in until the end.*

While these strategies were not coordinated, they clearly indicated that their withdrawal times were functions of the bank realization for any period.

For uninformed players it was clear that they attempted to condition their withdrawal on the actions of the informed. For example, consider the following statements of two of the subjects in the July 25 experiment whose statements best represented the behavior consistent with a separating equilibrium:

**Player 2 (Uninformed)**

*I tried to wait and see what the two informed players were doing. If they got out quickly, so did I. There was also a fair amount of intuition involved. Sometimes I went with the feeling to get out / stick with it when I was unsure of the moves of the informed. I tried to wait until period 4 if the informed had not moved in the first two periods. But sometimes I panicked and got out early.*

**Player 5 (Uninformed)**

*Because I was uninformed and knew that 2 were informed, I withdrew as soon as I saw 2 people had withdrawn their money.*

The remaining two players had the following to say:

**Player3 (Uninformed)**
*Wait until the last period, only withdraw earlier if people withdrew in the second period. I came up with this strategy only after a couple of rounds.*

**Player6 (Uninformed)**
*Waited until not too many people got out. If zero people came out in the first 2 time periods, I hold out till the 3rd period. If people withdrew in the beginning then I cashed out right after them.*

## INSTRUCTIONS

This is an experiment in group decision-making. A number of research foundations have funded this research and if you make good decisions you might be able to earn a considerable amount of money, which we will arrange to pay you when the experiment is over.

In these instructions we will first explain the decision problem you will engage in and then explain the experimental procedures you will use during the experiment.

### The Decision Problem

The decision problem you will engage in has the following structure. As you entered the lab you were randomly assigned to a group of six subjects who will be in your group for the entire 21 rounds of the experiment. In each round you will start out with 10 units of an experimental currency called francs which you must deposit in a "bank" which has promised to pay you compounded interest on your money at the rate of r' = 12% compounded at the end of each period. (These experimental francs will be converted into dollars at the end of the experiment at the rate of 1 franc = $1 in round 1 and 1 franc = $0.05 [five cents] in rounds 2-21. In other words, round 1 is twenty times as valuable to you as rounds 2-21).

The bank will pay you interest on your money until you withdraw it (at which time you will get your 10 francs back as well) but the longest you can keep your money in the bank is 4 periods. This means that if you keep your money in the bank for four periods and then withdraw it**,** if the bank has enough deposits to pay you, you will earn
$V = X (1 +.12)^4$ francs. The table below tells you how much you will earn if you deposited 10 francs in the bank before period 1 and withdraw it at the end of any of the four periods available and the bank has the funds to pay you. We will assume that the bank promises to pay you r' = 12% on your money:

| **Table 1: Promised Returns** | |
|---|---|
| **Date of Withdrawal** | **Payment** |
| 1 | 11.20 |
| 2 | 12.54 |
| 3 | 14.04 |
| 4 | 15.73 |

Looking at Table 1 we see that, at the promised rate of return, if you kept your money in the bank for four periods you would receive 15.73 francs which is your original amount of 10 francs compounded at the rate 12% for four periods. If you withdraw your money earlier, say in period 2, you would obviously receive less, i.e., 12.54 francs. **All this assumes that the bank is able to pay you.**

There are several reasons why the bank may not be able to pay you when you decide to withdraw and we will review them now.
First banks make money by borrowing from their clients at low interest rates and lending at higher ones. When you deposit your money in a bank they borrow from you and they promise to pay an interest rate which we are calling r' (this is the cost of the bank) and they hope to find investment opportunities that will return them at least that. If they don't, they will lose money. Therefore, the ability of a bank to be able to pay you what is promised depends on how the bank has invested its money, i.e. on its rate of return compared to what it promised to pay its depositors.

Put differently, let us assume that there are different quality banks in the world and you do not know what the quality of your bank is. A bank's quality measures the rate of return on its investments. More specifically, say there are 5 different qualities of banks that you could have invested your money in. **You will not be told the quality of your bank but you will be told the average quality or average rate of return of the five banks which we will call r*.** So if r* is the average or mean rate of return for banks in this five- bank banking industry, then we will assume that one bank will have a rate of return of 3/3(r*) (this will be the average bank), one will have a rate of return of 2/3(r*), one will have a rate of return of 1/3(r*) (these are the less than average banks), one will have a rate of return of 4/3(r*), and one will have a rate of return of 5/3(r*) (these are the above average banks). Which bank your money is in will not be told to you but we will tell you that the probability that your money is in any one of these five banks is equal. In other words, your money is equally likely to be in the average bank as it is in the worst bank yielding a return of 1/3(r*) as it is to be in the bank yielding the highest return of 5/3(r*), each has a 1/5 chance of occurring. We will call these banks, Banks 1, 2, 3, 4, and 5 with Bank 1 being that bank having the lowest rate of return ((1/3)r*) and Bank 5 having the highest (5/3r*).

So one factor that determines if the bank will be able to pay you your promised rate of return is whether the rate of return in the bank where your money is deposited is greater than the promised rate of return. If it is, then you will be able to get your 10 francs plus interest back whenever you want it, even if you keep it for four periods.

Another way to look at this is say that the average rate of return in the banking industry turns out to be 5% while the promised rate is 4.8%. Then there will be three banks such that if your money was deposited there you would be able to keep it in the bank for four periods and be sure to get paid your promised amount when you withdraw it. These are the average bank, and the two above average banks. Since there are five banks in total, the probability of being sure to get your promised return in this situation is 3/5 = 60%. If the promised rate of return was 5.1%, then only the two above average banks would be able to pay off as promised in any period no mater what people do, and this would have a 2/5 = 40% chance of occurring but there will be a 60% chance that when you go to withdraw your money from the bank, it will not be able to pay you what you were promised.

When the bank is not able to pay you what it promised, how much money you will eventually get will depend on when (what period) you take your money out of the bank and on how many people withdrew their money either before or at the same time as you. Your banks payment rule can be summarized as follows: **"Pay the promised return on any funds requested to be withdrawn if there is enough money in the bank to do so. If there is not, divide up what is available amongst those requesting payment"**

So, the longer your money is kept in the bank the more it grows because of compound interest. However, if during that period others take their money out they may leave insufficient funds for you especially if your money is deposited in a poor quality bank.

So whether you are able to receive your promised amount of money when you choose to withdraw it depends on the average rate of return in the banking industry because the higher that is the higher the return in your bank is no matter which bank your money is deposited in, and the number of people taking their money out before you. (Obviously you don't care how many of them take it out after you). The higher the rate of return, the more likely it is that you will be able to be paid when you want your money. The more people who withdraw before you the less likely you are to be paid.

**Note, however, that whenever the rate of return in the bank you deposited your money in is greater than the promised rate of return, then you will be paid your promised amount for sure no matter when you or anyone else withdraws their money. You only need to worry that you will not be paid when your bank has a rate of return on its investments less than your promised rate r'.**

**Payoff Tables and Calculators**

To help you understand the tradeoffs that exist here we will provide you with two things. First we will provide you with a set of tables marked **Period 1, Period 2, Period 3, and Period 4**, that will tell you how much you will be able to earn or what your payoff will be depending on various scenarios about the behavior of the other subjects in the experiment and on what bank your money happens to be deposited in. Put differently, these tables will tell you your payoff depending upon when you and everyone else decide to take out your money and which one of the five banks your money is in. We also show your expected or average payoff where the average is taken by incorporating the probability that your money is in any one of the five banks it can be in. (Remember, your money has an equally likely chance of being in any of five banks (Banks 1, …,5) whose return is either 1/3, 2/3, 3/3, 4/3, or 5/3's the average rate of return in the banking industry, r*).

**In addition, we will supply you with a calculator which will allow you to find out your expected payoff by asking it questions about various scenarios of behavior by yourself and others without having to check the table yourself. Let's see how to use the tables.**

Say that the average rate of return, r*, in the banking industry is 7% and you were promised r' = 12%. This would mean that if your money is in bank 4 or bank 5 then you will be paid your promised amount no matter what the other subjects do. However, if your money is in a 1, 2, or 3, then you will not be able to be paid your promised amount if you wait until period 4 to take your money out. How much you then are paid will depend on when you take your money out, when the others do, and on the bank your funds are deposited in. Let us see how this will work.

Say you are contemplating taking your money out in Period 3 and you want to know what your expected payoff will be when 3 people removed their money in period 1, 2 in removed it period 2, and you alone remove it in period 3.

Assume r* = 7% and r' = 12%. To find out what your expected payoff will be in this scenario, the first thing you should do is turn to the table marked **Period 3** since that will be the relevant table for you. On the **Period-3** table you will see a set of columns marked, *number removing money in Period 1*, *number removing money in Period 2*, and *number of others removing money in period 3*. Look down the columns until you see the row indicating scenario just described. It is highlighted in Yellow. In other words, look for the Row that has a 3 in column 1, a 2 in column 2, and a 0 in column 3. If you look across that row you will see how much you will earn depending on where your money is deposited. For example, if your money is in bank 1 whose rate of return is 2.3% then under the above scenario you would earn 3.4 francs. Clearly, with such a poor bank if the others took their money out before you then there would be little left for you. However, if your money was in bank 5 (the best bank), whose rate of return is 11.6%, then you would earn 13.6 francs under the same scenario. (Note that this payoff is still below the promised return of 15.7 francs). You can look and see what your payoff would be in case your money was in any of the other banks. Since the bank your money is in is random, however, you could expect a return of 8.4 francs.

Let's take another scenario. Say that r* = 7% and r' = 12% just as above. Say that you alone decide to take your money out in period 1, 2 people removed their money in period 2, 2 in period 3 and 1 in period 4. To find out what your payoff would be you must turn to the **Period 1** and look down the only column there to the row marked 0 indicating that you are the only one to remove at that time. As you can see your payoff would be 11.2 no matter what bank your funds are in since you will be paid your promised amount no matter what given all the funds in the bank and the fact that you alone are removing them. Under the same scenario say that instead of withdrawing your funds at period 1 you wait until period 3. In this case no people withdraw in period 1, 2 in period 2 and 3 in period three. To find your payoff here, look at the **Period 3** table and look at the row with a 0 in column 1, a 2 in column 2 and a 2 in column 3. Here we see that your payoff will be 12.9 francs if your money were invested in the worst bank but 14.0 if it were in the best bank. Your expected payoff from removing in period 3 is 13.8. So in this particular scenario, you would be better off removing your money in period 3 than in period 1. In other scenarios it could and would be different. To make sure you know how to use these payoff tables let us pause and have you answer the following questions.

**Payoff Quiz**

**1) Find the payoff under the following situation:**

The promised rate of return is r' = 12%, the average rate of return is r* = 7%. You want to withdraw your money in period 3 and want to know your payoff if 3 people withdraw their money in period 1, 0 people in period 2, and you are the only person who withdraws in period 3. Look at your payoff table to find the answer under the assumption that your money is in the second best bank. Also find your expected payoff under this scenario.
**The correct answer is 14.0 francs and 14.0 francs respectively for the second best bank and the expected payoff. If you did not get that answer try the next problem.**

2) Find the payoff under the following situation: r* = 7%, r' = 12%, everyone waits until the end of the experiment to withdraw his or her money and the money is deposited in the worst bank. Also find the expected payoff.
**The answer is 11.2 for the worst bank and 13.2 for the expected payoff.**

**If you did not answer these questions correctly raise you hand and we will come by and assist you.**

**The Calculator**

In order to make this process easier for you, we have provided you with a calculator that will enable you to find your hypothetical **expected** payoffs by simply feeding in scenarios into the calculator. (Note that this is your expected payoff and hence your actual payoff may differ since your funds will actually be in one and only one bank in any given round).

To enter the calculator simply click on the calculator button on your screen and you will be allowed to use it. When you click on the button you will see a screen that looks something like this.

**Time Period Selection for Player 1:**
**◘ period 1 ◘ period 2 ◘ period 3 ◘ period 4**
**Time Period Selection for Player 2:**
**◘ period 1 ◘ period 2 ◘ period 3 ◘ period 4**
**Time Period Selection for Player 3:**
**◘ period 1 ◘ period 2 ◘ period 3 ◘ period 4**
**Time Period Selection for Player 4:**
**◘ period 1 ◘ period 2 ◘ period 3 ◘ period 4**
**Time Period Selection for Player 5:**
**◘ period 1 ◘ period 2 ◘ period 3 ◘ period 4**
**Time Period Selection for Player 6:**
**◘ period 1 ◘ period 2 ◘ period 3 ◘ period 4**

Knowing which person or player you are enter any scenario by deciding how many other people you want to withdraw their money at various times. Note that it does not matter who withdraws at any time just the number of people doing it.

For example, lets look at our scenario above: You want to withdraw your money in period 3 and want to know your payoff if 3 people withdraw their money in period 1, 0 people in period 2, and you are the only person who withdraws in period 3. Say that you are player 6. One way to find your payoff is to assume that players 1,2, and 3 remove their money in period 1. Then click the period 1 button for each of them. Now click the period 3 button for yourself (player 6) and for players 4 and 5 click the period 4 button. By doing this you can find your expected payoff. (There are other ways to do it as well). This should give you an answer of 14.0 francs.

As a final example, find your expected payoff when you are Player 6, you and 2 others remove your money in period 2 and the remaining three other people remove their money in period 3. The answer should be 12.5 and if you did not get that answer please raise your hand.

At this point feel free to use the calculator and test yourself. It will remain available to you during the entire experiment.

**Experimental Procedures**

Now that you know the decision problem you will face, and how to calculate your payoff, let us explain how the exact experiment will proceed. After you have been assigned to a group of six subjects you will be awarded a fund of 10 francs which will be deposited into a bank account in one of five possible banks where the bank promises to pay you interest at the rate of r' = 12%. **All people in your group will have their money deposited into the same bank**. The bank your money is deposited in will earn a rate of return of either 1/3r*, 2/3r*, 3/3r*, 4/3r* or 5/3r*, where r* = 3/3r* is the average rate of return amongst the five banks.

The first thing that happens in the experiment is that you are informed of the average rate of return among the five banks, i.e., you will be told r*. This will occur by a message that will appear on your screen, which will say:

The Average Rate of Return is r* = 7%.

Next the computer will choose a bank into which to deposit your and all the other subjects' money, **but this will not be told to you.** All you will know is that there is an equal chance that your money will be in any one of the five banks.

Once this has occurred and you know your promised rate by the bank, r' = 12%, and the average rate of return among the five banks r* = 7%, you will have to decide when you want to withdraw your money. Before you make your decision you will be able to consult both the payoff table available to you and use your calculator to ask and answer any questions you want. When you are finished consulting these aids and have decided on your decision, the computer will prompt you:

**It is period 1 do you want to remove your money?**
**◘ Yes ◘ No 2**

You will then click either **Yes** or **No** and click the submit button to confirm. If you click **Yes,** your participation in this round of the experiment will be over and you must wait for the others to finish. If you click **No**, after each subject has decided about Period 1 the computer will prompt you:

**It is period 2 do you want to remove your money?**
**◘ Yes ◘ No 2.**

This will continue for four periods. Once you and all the other subjects have entered and confirmed your decisions, you will be given some information about what happened in that round. More precisely, you will be told your payoff, the rate of return in the bank your money was deposited in (which will be 1/3r* if it was deposited in the worst bank, 2/3r* if it was deposited in the second worst bank, etc.), your promised payoff, the number of people who withdrew their money in each period, and their promised and actual payoffs. (Note that if any subject's payoff equals their promised payoff, it means that the bank had enough money to pay what they owed in that period). This will be the end of round 1.

Round 2 will then start in exactly the same way. In each round the promised rate of return (r') and average rate of return (r*) will be identical. **(This means that for every round of the experiment r* = 7% and r' = 12% and this will not change.)** However, in each round the computer will randomly determine the bank into which all subject funds are deposited by choosing among the banks with equal probability. Hence, there is an equal chance that the bank will be any one of the five possible banks. **It is important to note that the probability that any bank is chosen in round 2 (or any other round) is independent of what bank was chosen in the previous (or any preceding rounds. Each round is independent of the past.**

Again, you will be asked to choose a period when you want to remove your money and be prompted by the prompt:

**Final Payoffs**

Your final earnings in the experiment will be the sum of your franc payoffs earned during each of the 21 rounds. However, the first of the 21 rounds will be worth 20 times as much as each of the remaining rounds. This means that while in the first round each franc will equal $1, each franc on the remaining rounds will be worth $0.05 or five cents. The first round could be worth as much as $15.75. Each of the remaining rounds are worth much less but their sum may still be substantial. You will be paid this amount when the experiment is over.

**Payoff Table for Sequential Low Information, r*=7% and r'=12%**

**Your Payoff if you withdraw at period 1**

| number of others removing money in period 1 | Bank 1 rate=2.3% | Bank 2 rate=4.6% | Bank 3 rate=7% | Bank 4 rate=9.3% | Bank 5 rate=11.6% | Average Payoff |
|---|---|---|---|---|---|---|
| 0 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 |
| 1 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 |
| 2 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 |
| 3 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 |
| 4 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 |
| 5 | 10.23 | 10.47 | 10.70 | 10.93 | 11.20 | 10.71 |

**Your Payoff if you withdraw at period 2**

| number removing money in period 1 | others removing money in period 2 | Bank 1 rate=2.3% | Bank 2 rate=4.6% | Bank 3 rate=7% | Bank 4 rate=9.3% | Bank 5 rate=11.6% | Average Payoff |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 0 | 1 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 0 | 2 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 0 | 3 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 0 | 4 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 0 | 5 | 10.47 | 10.96 | 11.45 | 11.95 | 12.47 | 11.46 |
| 1 | 0 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 1 | 1 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 1 | 2 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 1 | 3 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 1 | 4 | 10.27 | 10.80 | 11.34 | 11.90 | 12.46 | 11.36 |
| 2 | 0 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 2 | 1 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 2 | 2 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 2 | 3 | 9.98 | 10.57 | 11.18 | 11.81 | 12.45 | 11.20 |
| 3 | 0 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 3 | 1 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 3 | 2 | 9.48 | 10.19 | 10.91 | 11.66 | 12.43 | 10.94 |
| 4 | 0 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 | 12.54 |
| 4 | 1 | 8.49 | 9.42 | 10.38 | 11.37 | 12.40 | 10.41 |
| 5 | 0 | 5.53 | 7.12 | 8.77 | 10.50 | 12.28 | 8.84 |

**Your Payoff if you withdraw at period 3**

| number removing money in period 1 | number removing money in period 2 | number of others removing money in period 3 | Bank 1 rate=2.3% | Bank 2 rate=4.6 % | Bank 3 rate=7% | Bank 4 rate=9.3 % | Bank 5 rate=11. 6% | Average Payoff |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 0 | 1 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 0 | 2 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 0 | 3 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 0 | 4 | 12.86 | 13.76 | 14.05 | 14.05 | 14.05 | 13.75 |
| 0 | 0 | 5 | 10.72 | 11.47 | 12.25 | 13.07 | 13.92 | 12.29 |
| 0 | 1 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 1 | 1 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 1 | 2 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 1 | 3 | 12.87 | 13.92 | 14.05 | 14.05 | 14.05 | 13.79 |
| 0 | 1 | 4 | 10.29 | 11.13 | 12.02 | 12.94 | 13.91 | 12.06 |
| 0 | 2 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 2 | 1 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 2 | 2 | 12.88 | 14.05 | 14.05 | 14.05 | 14.05 | 13.81 |
| 0 | 2 | 3 | 9.66 | 10.63 | 11.66 | 12.75 | 13.88 | 11.72 |
| 0 | 3 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 0 | 3 | 1 | 12.89 | 14.05 | 14.05 | 14.05 | 14.05 | 13.82 |
| 0 | 3 | 2 | 8.60 | 9.80 | 11.08 | 12.42 | 13.84 | 11.15 |
| 0 | 4 | 0 | 12.95 | 14.05 | 14.05 | 14.05 | 14.05 | 13.83 |
| 0 | 4 | 1 | 6.48 | 8.14 | 9.91 | 11.78 | 13.76 | 10.01 |
| 0 | 5 | 0 | 0.12 | 3.15 | 6.39 | 9.84 | 13.51 | 6.60 |
| 1 | 0 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 1 | 0 | 1 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 1 | 0 | 2 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 1 | 0 | 3 | 13.14 | 14.05 | 14.05 | 14.05 | 14.05 | 13.87 |
| 1 | 0 | 4 | 10.51 | 11.31 | 12.14 | 13.01 | 13.92 | 12.18 |
| 1 | 1 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 1 | 1 | 1 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 1 | 1 | 2 | 13.24 | 14.05 | 14.05 | 14.05 | 14.05 | 13.89 |
| 1 | 1 | 3 | 9.93 | 10.85 | 11.81 | 12.83 | 13.89 | 11.86 |
| 1 | 2 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 1 | 2 | 1 | 13.45 | 14.05 | 14.05 | 14.05 | 14.05 | 13.93 |
| 1 | 2 | 2 | 8.97 | 10.09 | 11.28 | 12.53 | 13.85 | 11.34 |
| 1 | 3 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 1 | 3 | 1 | 7.03 | 8.57 | 10.21 | 11.94 | 13.78 | 10.31 |
| 1 | 4 | 0 | 1.22 | 4.01 | 6.99 | 10.17 | 13.55 | 7.19 |
| 2 | 0 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 2 | 0 | 1 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 2 | 0 | 2 | 13.61 | 14.05 | 14.05 | 14.05 | 14.05 | 13.96 |
| 2 | 0 | 3 | 10.21 | 11.06 | 11.96 | 12.91 | 13.90 | 12.01 |
| 2 | 1 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 2 | 1 | 1 | 14.00 | 14.05 | 14.05 | 14.05 | 14.05 | 14.04 |
| 2 | 1 | 2 | 9.33 | 10.38 | 11.48 | 12.64 | 13.87 | 11.54 |
| 2 | 2 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 2 | 2 | 1 | 7.58 | 9.00 | 10.51 | 12.11 | 13.80 | 10.60 |
| 2 | 3 | 0 | 2.33 | 4.87 | 7.59 | 10.50 | 13.59 | 7.78 |
| 3 | 0 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 3 | 0 | 1 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 3 | 0 | 2 | 9.70 | 10.66 | 11.68 | 12.75 | 13.88 | 11.74 |
| 3 | 1 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 3 | 1 | 1 | 8.14 | 9.43 | 10.81 | 12.27 | 13.82 | 10.89 |
| 3 | 2 | 0 | 3.44 | 5.73 | 8.19 | 10.82 | 13.63 | 8.36 |
| 4 | 0 | 0 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 | 14.05 |
| 4 | 0 | 1 | 8.69 | 9.86 | 11.11 | 12.43 | 13.84 | 11.19 |
| 4 | 1 | 0 | 4.55 | 6.59 | 8.79 | 11.15 | 13.67 | 8.95 |
| 5 | 0 | 0 | 5.65 | 7.45 | 9.39 | 11.48 | 13.72 | 9.54 |

## Your Payoff if you withdraw at period 4

| number removing money in period 1 | number removing money in period 2 | number removing money in period 3 | number of others removing money in | Bank 1 rate=2.3% | Bank 2 rate=4.6% | Bank 3 rate=7% | Bank 4 rate=9.3% | Bank 5 rate=11.6% | Average Payoff |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 5 | 10.97 | 12.00 | 13.11 | 14.29 | 15.55 | 13.18 |
| 0 | 0 | 1 | 4 | 10.28 | 11.46 | 12.72 | 14.08 | 15.52 | 12.81 |
| 0 | 0 | 2 | 3 | 9.26 | 10.65 | 12.15 | 13.75 | 15.48 | 12.26 |
| 0 | 0 | 3 | 2 | 7.56 | 9.30 | 11.18 | 13.22 | 15.41 | 11.33 |
| 0 | 0 | 4 | 1 | 4.15 | 6.59 | 9.26 | 12.15 | 15.27 | 9.48 |
| 0 | 0 | 5 | 0 | 0.00 | 0.00 | 3.48 | 8.93 | 14.85 | 5.45 |
| 0 | 1 | 0 | 4 | 10.53 | 11.65 | 12.86 | 14.15 | 15.53 | 12.94 |
| 0 | 1 | 1 | 3 | 9.57 | 10.89 | 12.31 | 13.85 | 15.49 | 12.42 |
| 0 | 1 | 2 | 2 | 7.97 | 9.62 | 11.41 | 13.34 | 15.42 | 11.55 |
| 0 | 1 | 3 | 1 | 4.77 | 7.08 | 9.59 | 12.33 | 15.29 | 9.81 |
| 0 | 1 | 4 | 0 | 0.00 | 0.00 | 4.16 | 9.30 | 14.90 | 5.67 |
| 0 | 2 | 0 | 3 | 9.88 | 11.13 | 12.48 | 13.94 | 15.50 | 12.59 |
| 0 | 2 | 1 | 2 | 8.38 | 9.94 | 11.63 | 13.46 | 15.44 | 11.77 |
| 0 | 2 | 2 | 1 | 5.39 | 7.56 | 9.93 | 12.51 | 15.32 | 10.14 |
| 0 | 2 | 3 | 0 | 0.00 | 0.41 | 4.83 | 9.66 | 14.94 | 5.97 |
| 0 | 3 | 0 | 2 | 8.80 | 10.26 | 11.85 | 13.58 | 15.46 | 11.99 |
| 0 | 3 | 1 | 1 | 6.01 | 8.04 | 10.27 | 12.70 | 15.34 | 10.47 |
| 0 | 3 | 2 | 0 | 0.00 | 1.37 | 5.50 | 10.03 | 14.99 | 6.38 |
| 0 | 4 | 0 | 1 | 6.63 | 8.52 | 10.60 | 12.88 | 15.36 | 10.80 |
| 0 | 4 | 1 | 0 | 0.00 | 2.34 | 6.17 | 10.40 | 15.04 | 6.79 |
| 0 | 5 | 0 | 0 | 0.12 | 3.30 | 6.84 | 10.76 | 15.08 | 7.22 |
| 1 | 0 | 0 | 4 | 10.76 | 11.83 | 12.99 | 14.22 | 15.54 | 13.07 |
| 1 | 0 | 1 | 3 | 9.85 | 11.12 | 12.47 | 13.93 | 15.50 | 12.58 |
| 1 | 0 | 2 | 2 | 8.35 | 9.92 | 11.62 | 13.46 | 15.44 | 11.76 |
| 1 | 0 | 3 | 1 | 5.33 | 7.53 | 9.91 | 12.51 | 15.32 | 10.12 |
| 1 | 0 | 4 | 0 | 0.00 | 0.35 | 4.80 | 9.66 | 14.94 | 5.95 |
| 1 | 1 | 0 | 3 | 10.17 | 11.36 | 12.64 | 14.03 | 15.51 | 12.74 |
| 1 | 1 | 1 | 2 | 8.76 | 10.24 | 11.84 | 13.58 | 15.46 | 11.98 |
| 1 | 1 | 2 | 1 | 5.95 | 8.01 | 10.25 | 12.69 | 15.34 | 10.45 |
| 1 | 1 | 3 | 0 | 0.00 | 1.31 | 5.47 | 10.02 | 14.99 | 6.36 |
| 1 | 2 | 0 | 2 | 9.17 | 10.56 | 12.07 | 13.70 | 15.47 | 12.20 |
| 1 | 2 | 1 | 1 | 6.57 | 8.49 | 10.59 | 12.87 | 15.36 | 10.78 |
| 1 | 2 | 2 | 0 | 0.00 | 2.27 | 6.14 | 10.39 | 15.04 | 6.77 |
| 1 | 3 | 0 | 1 | 7.19 | 8.97 | 10.92 | 13.06 | 15.39 | 11.11 |
| 1 | 3 | 1 | 0 | 0.01 | 3.24 | 6.81 | 10.75 | 15.08 | 7.18 |
| 1 | 4 | 0 | 0 | 1.25 | 4.20 | 7.48 | 11.12 | 15.13 | 7.84 |
| 2 | 0 | 0 | 3 | 10.45 | 11.58 | 12.80 | 14.12 | 15.53 | 12.89 |
| 2 | 0 | 1 | 2 | 9.14 | 10.54 | 12.06 | 13.70 | 15.47 | 12.18 |
| 2 | 0 | 2 | 1 | 6.52 | 8.46 | 10.57 | 12.87 | 15.36 | 10.76 |
| 2 | 0 | 3 | 0 | 0.00 | 2.21 | 6.11 | 10.38 | 15.04 | 6.75 |
| 2 | 1 | 0 | 2 | 9.55 | 10.86 | 12.28 | 13.82 | 15.49 | 12.40 |
| 2 | 1 | 1 | 1 | 7.14 | 8.94 | 10.91 | 13.05 | 15.39 | 11.08 |
| 2 | 1 | 2 | 0 | 0.00 | 3.17 | 6.78 | 10.74 | 15.08 | 7.16 |
| 2 | 2 | 0 | 1 | 7.76 | 9.42 | 11.24 | 13.24 | 15.41 | 11.41 |
| 2 | 2 | 1 | 0 | 1.14 | 4.13 | 7.45 | 11.11 | 15.13 | 7.79 |
| 2 | 3 | 0 | 0 | 2.39 | 5.10 | 8.12 | 11.48 | 15.18 | 8.45 |
| 3 | 0 | 0 | 2 | 9.93 | 11.16 | 12.50 | 13.94 | 15.50 | 12.61 |
| 3 | 0 | 1 | 1 | 7.71 | 9.39 | 11.23 | 13.23 | 15.41 | 11.39 |
| 3 | 0 | 2 | 0 | 1.04 | 4.07 | 7.42 | 11.10 | 15.13 | 7.75 |
| 3 | 1 | 0 | 1 | 8.33 | 9.87 | 11.56 | 13.41 | 15.43 | 11.72 |
| 3 | 1 | 1 | 0 | 2.28 | 5.03 | 8.09 | 11.47 | 15.18 | 8.41 |
| 3 | 2 | 0 | 0 | 3.52 | 6.00 | 8.76 | 11.83 | 15.22 | 9.07 |
| 4 | 0 | 0 | 1 | 8.89 | 10.32 | 11.88 | 13.59 | 15.46 | 12.03 |
| 4 | 0 | 1 | 0 | 3.41 | 5.93 | 8.73 | 11.82 | 15.22 | 9.03 |
| 4 | 1 | 0 | 0 | 4.65 | 6.90 | 9.40 | 12.19 | 15.27 | 9.68 |
| 5 | 0 | 0 | 0 | 5.79 | 7.80 | 10.05 | 12.55 | 15.32 | 10.30 |