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On the Effects of Deposit Insurance and Observability on Bank Runs: An Experimental Study*

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Abstract

We study the effects of deposit insurance and observability of previous actions on the emergence of bank runs by means of a controlled laboratory experiment. We consider three depositors in the line of a bank, who decide between withdrawing or keeping their money deposited. We have three treatments with different levels of deposit insurance which reflect the losses a depositor may incur in the case of a bank run. We find that different levels of deposit insurance and the possibility of observing other depositors' actions affect the likelihood of bank runs. When decisions are not observable, higher levels of deposit insurance decrease the probability of bank runs. When decisions are observable, this need not to be the case. These results suggest that (i) observability might be considered as a partial substitute of deposit insurance, and that (ii) the optimal deposit insurance should take into account the degree of observability (*JEL Codes*: G21, C90)

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1 Introduction

This paper investigates how deposit insurance and observability of previous actions affect the emergence of bank runs by means of a controlled laboratory experiment. In 2007, the run on the English bank Northern Rock heralded the recent financial turmoil. This bank suffered massive withdrawals within days despite that bank deposits in the UK were insured. Other financial institutions like the Washington Mutual, Countrywidebank or the IndyMac Bank in the US, or the Bank of East Asia in Hong Kong also have experienced bank runs. Media coverage that made observable the lines in front of the bank offices might have contributed to the protraction of the runs.

Deposit insurance is regarded as one of the pillars of modern financial safety nets. The main objective of deposit insurance is to protect depositors who cannot generally make an informed assessment of the risk that the bank to which their funds are entrusted may fail. During the recent crisis, one of the public aims has been to maintain the confidence in the financial intermediation and to avoid runs on banks without problems with the fundamentals. To this purpose, the level of deposit insurance has been increased worldwide. In the US, the deposit insurance changed from covering the first \$100.000 to the first \$250.000 in 2008. In the EU, the new Directive 2009/14/EC protects the first €100.000, in contrast with a minimum of 90% of the first €20.000 protected by the previous Directive. In the UK, deposit insurance covered 100% of the first £2.000 and 90% of the first £35.000 by the time of the run on Northern Rock. Several changes since then increased the limit until 100% of the first £85.000. These measures have been reinforced by some governments announcing an implicit unlimited protection to the deposits. Given the size of the bank system, the increase in the deposit insurance limits supposes the assumption of huge risks. Clearly, analyzing the effectiviness of different levels of deposit insurance would help policymakers to design adequate measures to prevent runs.

Descriptions of bank runs episodes (e.g. Sprague 1910; Wicker 2001; Bruner and Carr 2007) suggest that people are more likely to withdraw their deposits after observing that others did it as well. Empirical studies also support the idea that many depositors have information about what other depositors have done and react to this information. Kelly and O Grada (2000) examine the behavior of depositors during the panics of 1854 and 1857 in New York. The depositors were mostly Irish immigrants, and the county of origin in Ireland was the most important factor in whether they withdrew or not. The authors explain this result arguing that immigrants from the same county tended to cluster in neighborhoods of their own, making their decisions "observable" (i.e., when they decided to withdraw, others from the same county got information about it and prompted the observers to follow suit). Starr and Yilmaz (2007) use detailed data provided by a bank that suffered a run in Turkey in 2001. The authors group depositors according to their deposit size and study how the behavior of these groups depended on previous withdrawal hikes. They show that the behavior of depositor groups of different sizes was responsive to actions of their peers, but not always to the observable behavior of depositors of other groups. In a recent study, Iyer and Puri (2011) investigate the underlying reasons for a run that affected an Indian bank in 2001. Their results highlight that a depositor's likelihood to run is increasing in the fraction of other people in his/her social network that have run. Overall, these studies make clear that understanding how observability influences the existence of bank runs is also of first order importance.

We design an experiment to study how different levels of deposit insurance and observability of actions affect the emergence of bank runs. The lack of detailed data about depositors' behavior in real-world situations complicates the analysis of these issues. Carrying out laboratory experiments that mimick bank runs may be a useful way to shed light on the effectiveness of different levels of deposit insurance, given various degrees of observability of depositors' behavior. Laboratory experiments are uniquely suitable to address this question: by carefully manipulating the information that subjects receive, it is possible to study how depositors react to this information, avoiding the effect of other variables and focusing our attention on the effect of different levels of deposit insurance.

We study bank runs using a coordination game that follows the spirit of Diamond and Dybvig (1983). There are three depositors lining up at a bank, in which earlier they deposited their endowments of 40 monetary units (MU). Depositors are randomly assigned a position (that is made known to them). This position determines the order in which depositors choose between waiting or withdrawing their money from the bank.[1] Each depositor knows her own liquidity needs, which is private information. Following the literature, we consider two types of depositors. There is an impatient depositor who has an immediate need for funds and always withdraws her deposit. The other two depositors are patient, so they do not need their money urgently and decide whether to withdraw their funds from the bank or to keep them deposited.

Whether the other depositors' decisions are observable is determined by the position in the sequence and the informational setup. In this paper, we focus on two setups: the simultaneous and the sequential one. In the simultaneous setup depositors do not have any information about what other depositors have done whereas in the sequential setup each previous decision is observable and depositors acting early are aware that their decisions will be observed.

In the experiment, the impatient depositor is simulated by the computer and is forced to withdraw. The patient depositors choose between waiting or withdrawing during 15 rounds, with variation of information

[1] We use "keeping the money deposited" and "waiting" in an interchangeable manner. The assumption about the perfect knowledge of the position and positions being exogeously determined is often considered in theoretical models (Andolfatto et al 2007; Green and Lin 2003; Ennis and Keister 2009).

and position in each round. If both of the patient depositors decide to wait, they receive the highest possible payoff (70 MU). Withdrawal yields a lower, but a still relatively high payoff (50 MU) to the first two depositors who decide to withdraw, regardless of her liquidity needs.[2] The payoff for a depositor that withdraws after two withdrawals is 20 MU. Deposit insurance becomes relevant when a patient depositor waits alone. In this case, we consider three possible payoffs which correspond to three different treatments. When there is *no insurance*, the patient depositor who waits alone receives a payoff of 20 MU which is as low as the payoff she would receive upon withdrawal once the other two depositors have withdrawn.[3] In the case of *low insurance*, the patient depositor who waits alone receives a payoff (30 MU) that is lower than the initial endowment and lower than the payoff to the first two withdrawing depositors. Nevertheless, it is higher than the payoff in the no-insurance case. In the *high insurance* case, a depositor who waits alone receives her initial endowment (40 MU). Hence, when there exists high insurance a patient depositor cannot lose money compared with the initial endowment, but still the first and second depositors who withdraw receive a higher payoff. Given these payoffs, bank runs can be approached as a coordination problem, meaning that a patient depositor prefers to wait if the other patient depositor does it as well (Diamond and Dybvig 1983).

We define a bank run as a situation in which at least one of the patient depositors withdraws. While previous experiments study how the likelihood of bank runs varies as the level of deposit insurance changes, ours allows also for variation in observability. This new dimension is shown to be relevant since depositors' choices may be affected by other depositors' decisions as testified by our experiment. The possibility of observing early withdrawals may spark off a bank run despite high levels of deposit insurance. Though, if early depositors are observed to keep the money in the bank, bank runs would be less likely to occur. Our experimental data is in line with the latter hypothesis. We show that observability plays a role in the emergence of bank runs as the sequential setup decreases significantly the likelihood of bank runs with respect to the case of simultaneous decisions. As expected, deposit insurance is also important in reducing the likelihood of bank runs since both low and high insurance decrease the likelihood of bank runs in any of the two setups.

When investigating the interplay between the different levels of insurance and observability we find that their effects are not independent. If decisions are not simultaneous but sequential, deposit insurance decreases the likelihood of bank runs, but the effects of high and low insurance in our experiment are not significantly different. This is the main contribution of the paper, since it is shown that the effectiveness of different levels of deposit insurance depends on the degree of observability, a finding that is absent in

[2] The rationale for this payoff is that depositors receive their initial endowment (40 MU) plus an interesent rate (10 MU).

[3] Since the bank starts with 3×40= 120 MU, after two withdrawals that yield 50 MU, the bank has only 20 MU to be paid to the depositor who waits.

the literature. This fact has potentially important policy implications. Lately, many scholars have argued that the moral hazard associated to deposit insurance may do more harm than the benefits it gives. Moral hazard arises under deposit insurance because it lowers market discipline on bank risk taking. In this vein, Demirgüc-Kunt and Detragiache (2002) find that weaknesses in the deposit insurance arrangement increase the likelihood that a country will experince a banking distress. Since deposit insurance and observability are found to be partial substitute, our results suggest that bank runs can be prevented with a lower level of deposit insurance in environments characterized by high level of observability. Thus, the policymakers should investigate the degree of observability to design the optimal deposit insurance. For instance, if the policymaker considers that on-line banks decrease observability, then the level of deposit insurance for those institutions should be increased. The contrary is true if the level of observability is high (e.g., media reports extensively on financial issues or banks operate in a transparent way that makes information about other depositors' decision available).

The remainder of the paper is organized as follows. In Section 2 we review the relevant literature and relate it to our findings. In Section 3 we present the experimental design. We report our results in Section 4. Section 5 concludes and discusses our findings.

2 Related literature

Two of the main features of our paper are that bank runs are modeled as a coordination problem and that depositors are able to observe other depositors' decisions. Although the worsening of fundamental variables is an important explanation for the occurrence of bank runs (e.g. Gorton 1988), there exists evidence for the importance of coordination problems as well (e.g. Calomiris and Mason 2003). The seminal paper in this literature is Diamond and Dybvig (1983) who use a simultaneous-move framework to show that bank runs can emerge as an equilibrium outcome. Most of the theoretical literature builds on the assumption of simultaneous decisions with the exception of a very few papers that have recently incorporated the idea of observability of actions. Ennis and Keister (2011), for instance, consider that depositors observe withdrawals as they occur. Kiss, Rodriguez-Lara and Rosa-Garcia (2009) do also allow for the possibility of observing other depositors' actions by considering a social network that channels information.[4] Our experimental data suggest that observability might foster coordination and avoid bank runs. We then provide evidence supporting the idea to incorporate observability into the theoretical models.

[4] Gu (2011) is another paper that incorporates the idea of observability. She focuses on a signal extraction problem in which depositors try to find out whether their bank has fundamental problems or not, so she leaves aside the idea of modeling bank runs as a coordination problem.

Our paper is also related to the literature on deposit insurance. The central issue in deposit insurance design is to strike the right balance between the benefits of avoiding crises (e.g. preventing wasteful fire sale of bank assets) and the costs of controlling bank risk taking (the moral hazard problem). This literature identifies partial insurance as an important element of good design (Demirgüc-Kunt, Kane and Laeven 2008), and states that high level of insurance lowers market discipline (Demirgüc-Kunt and Huizinga 2004). Our contribution to this literature is to point out that the optimal level of deposit insurance should take into account the degree of observability. This factor should be considered along others already identified by the literature for the optimal level of deposit insurance, such as the stage of development of the financial system, the macroeconomic conditions, or the political environment (for more details see Demirgüc-Kunt, Kane and Laeven 2008).

The experimental literature on bank runs studies factors that most favor or prevent them. This literature singles out deposit insurance as an important element that might prevent bank runs. Madies (2006) finds in a simultaneous-move framework that partial deposit insurance neither prevents nor stops the propagation of bank runs, as even depositors with a 75% insurance do not behave differently from uninsured depositors. In Schotter and Yorulmazer (2009), depositors observe the number of depositors that have withdrawn and the amount that has been withdrawn. In this setup that allows observability, deposit insurance guaranteeing 50% of the initial deposit helps to decrease the occurrence of bank runs, whereas the 20% insurance level does not affect depositors' behavior compared with the no-insurance case. In contrast to Madies (2006), we find that higher level of insurance leads to less bank runs in the simultaneous setup. Our findings support Schotter and Yorulmazer (2009) in the sequential setup as partial insurance effectively lowers the likelihood of bank runs.[5] Our contribution is to show that observability might be considered as a partial substitute of deposit insurance, so that optimal deposit insurance should take into account the degree of observability. This finding goes one step further than the empirical evidence provided by Iyer and Puri (2011), who highlight the importance of deposit insurance and observability of actions. The authors show that deposit insurance is partially effective and observability affects the propagation of bank runs, but they do not analyze the interplay between the two.

[5] The rest of papers that investigate bank runs as coordination problems in the lab (Arifovic, Jiang and Xu 2010; Garratt and Keister 2009; Kiss, Rodriguez-Lara and Rosa-Garcia 2009; Klos and Sträter 2011), do not consider the role of deposit insurance.

3 Experimental Design

A total of 192 students were recruited from the undergraduate population of the Universidad de Alicante. Students had no (or very little) prior exposure to game theory. The experiment was conducted at the Laboratory of Theoretical and Experimental Economics (LaTEx), using the experimental software z-Tree (Fischbacher 2007). The laboratory consists of 24 computers in separate cubicles and any form of communication between subjects was strictly forbidden.

We used a between-subject design and ran a total of 8 sessions, which correspond to three different treatments as detailed below. In each session, instructions were read aloud. We let subjects ask about any doubts they may have had before starting the experiment.[6] The average length of each session was 45 minutes. Subjects received on average 12 Euros for participating, including the show-up fee of 4 euros.

In each session, subjects were divided into two matching groups of 12. Subjects from different matching groups never interacted with each other throughout the session. Within the same matching group, subjects were randomly and anonymously matched in pairs at the beginning of each round. Each of these pairs was assigned a third depositor, simulated by the computer so as to create a three-depositor bank in each round. Subjects knew that one of the depositors in the bank was simulated by the computer.

In each session, the three depositors played a coordination problem for 15 rounds. In each round, depositors invested an initial endowment of $e = 40$ monetary units (MU) in the bank.[7] Then, they were randomly assigned a position in the sequence of decisions and asked to decide consecutively, as if they were in the line of a bank. Subjects knew their position in the line. It was known that the the computer was programmed to withdraw always, regardless of the position in the sequence. The subjects were allowed to decide between waiting or withdrawing in each round. Before making this decision, depositors possibly observed previous decisions within the same round and they knew whether they would be observed by subsequent depositors. In the experiment, we considered different information structures in each round.[8]

[6] The instructions for the experiment are originally in Spanish. A translated version is available in the web Appendix.

[7] We used Spanish pesetas as experimental currency. The reason for this design choice is twofold. First, it mitigates integer problems, compared with other currencies (USD or euros, for example). On the other hand, although Spanish pesetas are no longer in use, Spanish people still use pesetas to express monetary values in their everyday life. In this respect, by using a "real" currency we avoid the problem of framing the incentive structure of the experiment using a scale (e.g., "experimental currency") with no cognitive content.

[8] Subjects faced a different problem in each round. We studied all informational setups that may arise with three depositors, so we also had structures with partial information. For instance, depositor 3 may know what depositor 2 has done but she may have no information about depositor 1's decision. Results for the partial environments are similar to those discussed and are available upon request. An interesting question is whether subjects faced each round as a "new game" or they learnt how to play. The Chow test reveals that subjects did not behave differently in the second half (rounds 8 to 15) of the experiment.

To describe depositors' payoffs, let $y^i \in \{0,1\}$ for $i = 1,2,3$ denote the decision of depositor in position i, where 0 denotes keeping the money in the bank and 1 indicates withdrawal. We denote as c_1^i depositor i's payoff upon withdrawal and c_0^i the payoff if she waits. If a depositor decides to withdraw, she receives her payoff immediately. Payoff upon withdrawal is $c_1^i = 50$ for $i \in \{1,2\}$, and for $i = 3$ it is

$$c_1^3 = \begin{cases} c_1 = 50 \text{ if } \sum_{j \neq 3} y^j < 2 \\ c_{11} = 20 \text{ if } \sum_{j \neq 3} y^j = 2 \end{cases}.$$

In words, if depositor 1 or 2 withdraws, she receives $c_1 = 50$. This amount corresponds to the depositor's initial endowment ($e = 40$) plus an interest rate of 10 MU. If depositor 3 withdraws, she receives $c_1^3 = 50$ if she is the first or second withdrawing depositor. If depositor 3 withdraws after two withdrawals, then she gets the remaining funds in the bank ($c_{11} = 3e - 2c_1 = 20$) which is less than her initial endowment.

If a depositor chooses to keep the money in the bank, she has to wait until everybody has decided. If both subjects wait, then each of them receives 70 MU. Deposit insurance becomes effective if there is only one depositor who decides to wait.[9] We study three levels of insurance. In the case of no insurance (NO) the depositor lacks any protection and receives the residual funds the bank has after two withdrawals (20 MU). We ran two sessions with this treatment (48 subjects). In the case of low insurance (LOW) the only depositor who decides to keep her funds deposited receives a higher payoff (30 MU), but this payoff is still smaller than her initial endowment. We ran two sessions with this treatment as well (48 subjects). High insurance ($HIGH$) means that a depositor who chooses to wait cannot lose money, so she receives 40 MU.[10] Four sessions were run with this treatment (96 subjects). Payoffs for any subject $i \in \{1,2,3\}$ who decides to wait are:

$$c_0^i = \begin{cases} c_{00} = 70 \text{ if } \sum_{j \neq i} y^j = 1 \\ c_{01}^{NO} = 20 \text{ if } \sum_{j \neq i} y^j = 2 \\ c_{01}^{LOW} = 30 \text{ if } \sum_{j \neq i} y^j = 2 \\ c_{01}^{HIGH} = 40 \text{ if } \sum_{j \neq i} y^j = 2 \end{cases},$$

where the first symbol (0) in the subscript shows that depositor i waits, while the second symbol denotes the other subject's decision. Superscripts stand for the treatment.

Payoffs resemble the *ex ante* optimal contract in Diamond and Dybvig (1983) and allow for coordination problems, satisfying the following relations:

$$c_{00} > c_1 > e \geq c_{01}^D \geq c_{11},$$

[9] In the experiment we did not use the word "deposit insurance". See the Instructions in the web Appendix for further details.

[10] Note that we are always considering the case of a partial insurance because the accrued interest rates are not protected. The same design is implemented in Madies (2006) and Schotter and Yorulmazer (2009).

where $D \in \{NO, LOW, HIGH\}$ represents the level of deposit insurance.[11] A key element is that when depositors decide, they know their position but they may not be sure of the payoff they will receive. For instance, imagine a subject in position 2 who observes a withdrawal. She does not observe whether the withdrawal was due to the other subject or the computer. In the first case, the maximum payoff she may receive is 50 MU whereas in the latter case she may obtain 70 MU depending on the decision of depositor 3. Similarly, if depositor 3 in the simultaneous setup decides to withdraw, she does not know whether she will receive $c_1 = 50$ or $c_{11} = 20$.

We define a bank run as a situation in which at least two withdrawals occur. This is the broadest definition, according to which a withdrawal due to a subject (other than the computer) already constitutes a bank run.[12] Hereafter, we study how deposit insurance and observability affect the likelihood of bank runs. In the simultaneous setup, subjects knew their position but were not aware of predecessor's actions. In the sequential setup subjects knew the decisions of their predecessors and that their decision would be observed by subsequent subjects. The fact that decisions are observable in the sequential setup is in line with the empirical evidence presented in the introduction, which also suggests that (i) depositors react quick to this information (e.g., Starr and Yilmaz 2007) and that (ii) the bank's assets available to pay off depositors may decline faster than observability reveals withdrawals (i.e., the bank in our experiment cannot pay 50 MU to all depositors who decide to withdraw). Our payoffs then have the same structure as in Garratt and Keister (2009) Schotter an Yorulmazer (2009).

4 Experimental Evidence

In this section we analyze the data gathered during the experimental sessions. The main results and insights are summarized in Table 1. In this table, we report the relative frequency of bank runs in each treatment. We present the data for both the simultaneous and the sequential setup separately. The number of observations appears in brackets.

[11] Since Green and Lin (2003) part of the theoretical literature has focused on the design of incentive compatible contracts that prevent bank runs. These contracts require that the bank should know the depositors' utility function. This condition cannot be met in a lab experiment. Instead, we take a contract that allows for the coordination problem in Diamond and Dybvig (1983) and study whether the likelihood of bank runs is affected by the level of deposit insurance and the degree of observability.

[12] Bank runs might be also thought as a situation in which "too many" withdrawals take place in a "short" period of time. Our model does not consider this option since we follow the literature in which only the number of withdrawals (and not its speed) matters.

Table 1

We observe that different levels of deposit insurance affect the likelihood of bank runs in a different way. Table 1 shows that deposit insurance reduces the relative frequency of bank runs, as this frequency is higher when there is no insurance both in the simultaneous and the sequential setup. Other insight is that observability has a crucial effect, since bank runs are less likely in the sequential setup except for the case of high insurance. In fact, the third important finding is that the effect of observability and deposit insurance are not independent. Although low and high insurance affect differently the likelihood of bank runs in the simultaneous setup, it does not seem to be the case in the sequential one. More precisely, we see that the relative frequency of bank runs in the simultaneous setup decreases, as the level of insurance increases. It does not happen in the sequential case, in which increasing the level of insurance from low to high does not help to reduce the relative frequency of bank runs.[13]

In order to clarify the effects of deposit insurance and observability, we estimate a logit model in which the dependent variable is the probability of bank run. The dummy variables LOW and $HIGH$, take the value 1 when there exists low and high insurance respectively, being 0 otherwise. We define SEQ as a dummy variable that takes the value 1 if the setup is sequential, and it is 0 if it is simultaneous. We propose the following specification:

$$\Pr(\text{Bank Run}) = F(\alpha_0 + \alpha_{LOW}LOW + \alpha_{HIGH}HIGH + \alpha_{SEQ}SEQ + \alpha_{LOWSEQ}LOWSEQ + \alpha_{HIGHSEQ}HIGHSEQ) \tag{1}$$

where $F(z) = e^z/(1+e^z)$ and the variables $LOWSEQ$ and $HIGHSEQ$ capture the interaction effects. We run equation (1) over a total of 760 observations, which correspond to 760 banks, each of them with 2 subjects and the computer. We report the marginal effects of the different explanatory variables in the column (A) of Table 2. In column (B), the marginal effects of low and high insurance in the sequential setup are reported. The standard errors take into account matching group clustering.

Table 2

The baseline scenario is the simultaneous setup, when there is neither deposit insurance nor information about other depositors' decisions. In column (A), first we look at the effects that deposit insurance and observability have separately. We observe that when the low insurance is implemented in the simultaneous setup, the likelihood of bank runs decreases by roughly 35%; whereas the high deposit insurance reduces

[13] The test of proportion rejects the hypothesis that LOW and $HIGH$ has the same effect in the simultaneous setup ($z = 4.985$, $p-value = 0.000$), but this hypothesis cannot be rejected when decisions are sequential ($z = 0.685$, $p-value = 0.493$).

this likelihood by approximately 60%. We also see that observability reduces the likelihood of bank runs, since the marginal effect of SEQ is 23%. The fact that all these probabilities are significantly different from zero implies that deposit insurance and observability decrease the likelihood of bank runs. If we test the null hypothesis that deposit insurance and sequentiality have the same effect on reducing the likelihood of bank runs, we reject that hypothesis at 5% significance level. (For the null hypothesis $H_0 : \alpha_{LOW} = \alpha_{SEQ}$, we get $\chi^2_1 = 5.32$ and $p - value = 0.0211$. In the case of the null hypothesis $H_0 : \alpha_{HIGH} = \alpha_{SEQ}$, we get $\chi^2_1 = 40.80$ and $p - value = 0.0000$.) We also reject the null hypothesis that partial insurance and full insurance are equally important so as to reduce the likelihood of bank runs ($\chi^2_1 = 23.91$ and $p - value = 0.0000$). These findings are summarized as follows:

Result 1. *Deposit insurance and observability significantly reduce the likelihood of bank runs. We reject the hypothesis that these variables have the same effect. More specifically, we observe that high insurance has the largest effect, followed by low insurance and observability.*

The literature has shown the importance of deposit insurance to prevent bank runs. Our contribution is to indicate that observability of actions is also an essential factor in the emergence of bank runs. One unanswered question in the literature concerns the interplay between deposit insurance and observability. In column (A) we see that $LOWSEQ$ is not significantly different from zero. This indicates that partial insurance and observability do not have any additional joint effect on reducing the likelihood of bank runs apart from the effect that these variables have separately (i.e., the combined effect is the summation of both effects). As a result, we find that if there exists low insurance (observability), introducing observability (low insurance) significantly decreases the likelihood of bank runs (i.e., we reject both the hypothesis that $H_0 : \alpha_{SEQ} + \alpha_{LOWSEQ} = 0$ because $\chi^2_1 = 12.85$ and $p - value = 0.0003$, and the hypothesis that $H_0 : \alpha_{LOW} + \alpha_{LOWSEQ} = 0$, because $\chi^2_1 = 25.65$ and $p - value = 0.0000$). Finally, we also see in column (A) that the marginal effect of $HIGHSEQ$ is positive and significantly different from zero. Therefore, the total effect of having full insurance and a sequential setup is not just the sum of the individual effects. More precisely, high insurance has an additional effect on reducing the likelihood of bank runs once observability is in place (we reject the hypothesis that $H_0 : \alpha_{HIGH} + \alpha_{HIGHSEQ} = 0$, given that $\chi^2_1 = 29.65$ and $p - value = 0.0000$). However, observability does not have any impact on reducing the likelihood of bank runs if high insurance already exists (i.e., we cannot reject the hypothesis that $H_0 : \alpha_{SEQ} + \alpha_{HIGHSEQ} = 0$ at any common significance level because $\chi^2_1 = 0.50$ and $p - value = 0.4774$). We summarize these findings as follows:

Result 2. *Once depositors' decisions are observable, both low and high insurance have a significant additional decreasing effect on the likelihood of bank runs. If we add observability to low insurance, the* *likelihood of bank runs significantly decreases. Nevertheless, adding observability to high insurance does not have a significant effect on the likelihood of bank runs.*

This finding suggests that if the level of deposit insurance is low, the higher the degree of observability the less likely are bank runs.[14] The fact that observability is still important when depositors have the low insurance but it ceases to be relevant when the insurance increases suggests a relationship between the optimal level of deposit insurance and observability. In the column (B) of Table 2, we study the impact that both low and high insurance have on the likelihood of bank runs when depositors decide sequentially. We observe that both levels of deposit insurance decrease this likelihood by roughly 35%. Statistical test confirms that no significant difference is observed between the impact of low and high insurance in this setup (i.e., in the regression Pr(Bank Run| $SEQ = 1) = F(\gamma_0 + \gamma_{LOW} + \gamma_{HIGH})$, where $F(z) = e^z/(1+e^z)$, we fail to reject the null hypothesis $H_0 : \gamma_{LOW} = \gamma_{HIGH}$, since $\chi^2_1 = 0.46$ and $p - value = 0.4774$). We summarize this result as follows:

Result 3. *If depositors' decisions are not observable, high insurance has a different effect than low insurance on decreasing the likelihood of bank runs. It is not the case when decisions are observable.*

This result is important as it highlights that if financial intermediation is characterized by an information structure that allows observability, then there is no need to provide high level of deposit insurance. The effect of a properly chosen partial insurance cannot be enhanced necessarily by a higher one. It has two important consequences. On the one hand, in an environment characterized by plentiful information less insurance is enough to reduce the likelihood of bank runs. On the other hand, these experimental results suggest that the goal of minimizing the likelihood of bank runs without increasing unnecessarily the moral hazard caused by the existence of deposit insurance can be achieved, at least when depositors are able to observe each other.

5 Conclusion

We have studied the effects of deposit insurance and observability on the emergence of bank runs by means of a controlled laboratory experiment that aims to disentangle the effects of these factors and analyze their relationship. We find that when depositors' decisions are simultaneous, low and high insurance significantly

[14] A possible interpretation for this result is that if the deposit insurance is low, bank runs could be curbed if banks reveal to some extent depositors' actions. We acknowledge, however, that the degree of observability cannot be always controlled as it depends on the financial and legal environment.

decrease the likelihood of bank runs, both levels of deposit insurance having a different effect. When depositors' decisions are observable, we do not find any significant difference between the effect of low and high insurance.

Our contribution is to show that (i) observability might be considered as a partial substitute of deposit insurance, and that (ii) the optimal deposit insurance should take into account the degree of observability. These findings have implications for setting the optimal level of deposit insurance. In particular, our data suggest that an optimal deposit insurance scheme should rely upon the information structure (i.e., the information that depositors have about other depositors' decisions) so that there is no need to provide high levels of insurance to depositors when the degree of observability is high. In such an environment the likelihood of bank runs can be reduced without increasing exceedingly the moral hazard implied by high level of deposit insurance. Thus, if policymakers want to design adequate measures that offset moral hazard and contribute to the financial stability (Demirgüc-Kunt and Detragiache 2002) then more attention should be paid to investigate the level of observability.

It remains to be discussed, however, whether (and how) an optimal deposit insurance scheme could be determined as a function of bank-specific observability in the real life. We acknowledge that it is not straightforward to address this point. The empirical studies cited earlier highlight the importance of observability of actions but do not provide a clear measure of it. We consider that the foremost challenge to this literature may be the current lack of indexes that indicate how depositors communicate with each other. To contribute to this debate, we would like to point out some features that could be taken into account while constructing such an index. Consider the case of online and traditional banking. It seems safe to assume that the latter implies a higher degree of observability, so that it warrants requiring higher deposit insurance for those banks whose operations are done mostly through their online system.[15] The size of the banks could also be considered as a proxy for the degree of observability as small, local banks, where all depositors belong to the same community could be protected with a lower level of deposit insurance given that it is more likely that actions will be observed in that environment. Of course, the dispersion of the population and the existence of clusters or communities among the clients of the banks should also be considered while accounting for the level of observability of actions, as suggested by Kelly and O Grada (2002). The type of customers of each bank is an important factor at stake too. If banks have different kinds of depositors then the degree of observability will be probably smaller than if depositors are somehow "homogenous". This latter insight is gleaned from Starr and Yilmaz (2007) where it is found that small depositors are quite responsive to other

[15] Some of the recent bank runs have been initiated when too many depositors tried to withdraw online their savings, e.g. when Wachovia faced a silent bank run in 2008.

small depositors' withdrawal whereas they are only marginally responsive to shocks coming from medium-size depositors and are unresponsive to large depositors' increased withdrawal rates. This result is explained because small depositors are not always able to observe large depositor's actions.

Clearly, the previous considerations are just the first steps toward designing an optimal deposit insurance scheme that takes into account the degree of observability. We agree that "communication channel traffic needs to be directly measured" (Devenow and Welch 1996, p. 612). In their study, Devenow and Welch (1996) focus on herding behavior in financial markets and they helped to spark further investigation into the ways in which observability of actions affect decisions in the equity markets. We think that the same steps can be followed when analyzing the depositors' behavior in financial intermediation.

Although our model incorporates sequential decisions and generalizes the model of Diamond and Dybvig (1983), we do not consider the case of depositors deciding when to go to the bank. We lack theoretical models and empirical evidence in this regard. Building models that incorporate timing in the spirit of Gul and Lundholm (1995) and carrying out lab experiments allowing to choose when to withdraw would be fruitful areas for future research. Incorporating aggregate uncertainty into the model (e.g., the number of impatient depositors is unknown, as in Garratt and Keister 2009) is also a nice step for future research in this area.

References

[1] Andolfatto, David, Ed Nosal, and Neil Wallace. (2007) "The role of independence in the Green-Lin Diamond-Dybvig Model." *Journal of Economic Theory*, 137, 709-715.

[2] Arifovic, Jasmina, Janet H. Jiang, and Yiping Xu. (2010) "Bank Runs as Pure Coordination Failures: Experimental Evidence and Endogenous Evolutionary Learning." Mimeo.

[3] Bruner, Robert F., and Sean D. Carr. (2007) *The Panic of 1907: Lessons Learned from the Markets Perfect Storm*. John Wiley & Sons.

[4] Calomiris, Charles W., and Joseph R. Mason. (2003) "Fundamentals, Panics and Bank Distress During the Depression." *American Economic Review*, 93, 1615-47.

[5] Demirgüc-Kunt, Asli, and Enrica Detragiache. (2002) "Does deposit insurance increase banking system stability? An empirical investigation." *Journal of Monetary Economics*, 49, 1373-1406.

[6] Demirgüc-Kunt, Asli, and Harry P. Huizinga. (2004) "Market discipline and deposit insurance." *Journal of Monetary Economics*, 51, 375-399.

[7] Demirgüc-Kunt, Asli, Edward J. Kane, and Luc Laeven. (2008) *Deposit Insurance around the World: Issues of Design and Implementation*. Cambridge, MA:The MIT Press.

[8] Devenow, Andrea, and Ivo Welch. (1996) "Rational herding in financial economics." *European Economic Review*, 40, 603-615.

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

[10] Ennis, Huberto M., and Todd Keister. (2009) "Run equilibria in the Green–Lin model of financial intermediation." *Journal of Economic Theory*, 144, 1996-2020.

[11] Ennis, Huberto M., and Todd Keister. (2011) "Optimal Banking Contracts and Financial Fragility." Mimeo.

[12] Fischbacher, Urs. (2007) "z-Tree: Zurich toolbox for ready-made economic experiments." *Experimental Economics*, 10, 171-178.

[13] Garratt, Rod, and Todd Keister. (2009) "Bank runs as coordination failures: An experimental study." *Journal of Economic Behavior and Organization*, 71, 300-317.

[14] Gorton, Gary. (1988) "Banking Panics and Business Cycles." *Oxford Economic Papers*, 40, 751-781.

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

[16] Gu, Chao. (2011). "Herding and Bank Runs." *Journal of Economic Theory*, 146, 163-188.

[17] Gul, Faruk, and Russell Lundholm. (1995) "Endogenous Timing and the Clustering of Agents' Decisions." *Journal of Political Economy*, 103, 1039-1066.

[18] Iyer, Rajkamal, and Manju Puri. (2011) "Understanding Bank Runs: The Importance of Depositor-Bank Relationships and Networks." *American Economic Review*, forthcoming.

[19] Kelly, Morgan, and Cormac Ó Gráda. (2000) "Market Contagion: Evidence from the Panics of 1854 and 1857." *American Economic Review*, 90, 1110-1124.

[20] Kiss, Hubert J., Ismael Rodriguez-Lara, and Alfonso Rosa-García. (2009) "Do Social Networks Prevent Bank Runs?." IVIE Working Papers, Serie AD 2009-25.

[21] Klos, Alexander, and Norbert Sträter. (2011) "Level-1 Thinking in an Experimental Bank Run Game." Working paper, Finance Center Münster.

[22] Madies, Philippe. (2006) "An Experimental Exploration of Self-Fulfilling Banking Panics: Their Occurrence, Persistence, and Prevention." *Journal of Business*, 79, 1831-1866.

[23] Schotter, Andrew, and Tanju Yorulmazer. (2009) "On the dynamics and severity of bank runs: An experimental study". *Journal of Financial Intermediation*, 18, 217-241.

[24] Sprague, Oliver M. (1910) *History Of Crises Under The National Banking System*. Washington, DC: U.S. Government Printing Office.

[25] Starr, Martha A., and Rasim Yilmaz. (2007) "Bank Runs in Emerging-Market Economies: Evidence from Turkey's Special Finance Houses." *Southern Economic Journal*, 73, 1112-1132.

[26] Wicker, Elmus. (2001) *The Banking Panics of the Great Depression*. Cambridge: Cambridge University Press.

6 Tables

Table 1. Relative frequency of Bank Runs in each Treatment

	Treatment		
	No Insurance	Low Insurance (LOW)	High Insurance (HIGH)
Simultaneous	0.841	0.483	0.225
	(120)	(120)	(240)
Sequential	0.657	0.214	0.257
	(70)	(70)	(140)

The number of observations appears in brackets. In total, we have 760 observations, each corresponding to a bank with 2 experimental subjects (i.e., observations correspond to a total of 1520 decisions).

Table 2. Logit model for the likelihood of bank runs in each set up

	Likelihood of *Bank Run*			
	(A) Simultaneous		(B) Sequential	
	Coef.	Std. Error	Coef.	Std. Error
Low Insurance (LOW)	**-0.355****	*0.052*	**-0.345****	*0.053*
High Insurance (HIGH)	**-0.606****	*0.046*	**-0.365****	*0.063*
Sequentiality (SEQ)	**-0.234***	*0.077*	.	.
LOWSEQ	-0.050	*0.114*	.	.
HIGHSEQ	**0.290***	*0.099*	.	.
Log-Likelihood	-424.67886		-161.181	
Pseudo R^2	0.1735		0.1078	
Number of observations	760		280	

We have 760 observations which correspond to 1520 decisions. The second column with 250 observations represents the case when we condition the reg on the sequential setup. The marginal effects reported in Table 2 are significantly different from zero at **1% or *5% significance level.