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Would depositors pay to show that they do *not* withdraw? Theory and experiment

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Abstract

In a Diamond–Dybvig type model of financial intermediation, we allow depositors to announce at a positive cost to subsequent depositors that they keep their funds deposited in the bank. Theoretically, the mere availability of public announcements (and not its use) ensures that no bank run is the unique equilibrium outcome. Multiple equilibria—including bank run—exist without such public announcements. We test the theoretical results in the lab and find a widespread use of announcements, which we interpret as an attempt to coordinate on the no bank run outcome. Withdrawal rates in general are lower in information sets that contain announcements.

Keywords Asymmetric information · Bank runs · Experimental evidence · Public information

JEL Classification C72 · C91 · D80 · G21

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1 Introduction

Mitigating the potential for bank runs has not been an important policy concern in developed economies since the Great Depression. Interest in financial fragility has peaked in recent years, however, with the 2007–2009 financial crisis, which was heralded by a run on the British bank Northern Rock. In distinction to earlier episodes of bank runs, the run at Northern Rock was initiated not by a panic among small retail depositors, but by large institutional investors who stopped rolling over short term loans and lending on the overnight market.

For the case of Northern Rock, Shin (2009) finds that the coordination failure among these institutional investors was the prime source of the breakdown of lending, leading eventually to bankruptcy. Other financial institutions (such as the US investment bank Bear Stearns and the US insurer AIG) suffered a similar fate.[1] Thereafter, retail banks, such as DSB Bank in the Netherlands or Bankia in Spain, were also run. While deteriorating fundamentals are a prime cause of bank runs, there was often a substantial self-fulfilling component in the depositors' behavior. Depositors hurry to withdraw fearing that other depositors will also do so, and if they arrive late, they risk to lose their deposits.

In order to prevent bank runs (on fundamentally healthy institutions) caused by miscoordination, we propose a new procedure. We show that this procedure eliminates bank runs in the theoretical model as well as reduces its occurrence in laboratory experiments. Our analysis is based on Diamond and Dybvig (1983)'s seminal paper in which depositors play a *simultaneous-move* coordination game.[2] This model yields two symmetric equilibria: *(i)* a *bank run*, when everybody rushes to withdraw from the bank, and *(ii) no bank run*, when only those who need liquidity withdraw. This model adequately captures some real situations in which depositors do not observe each other's actions.[3] In many situations, however, depositors decide sequentially and receive some additional information before making a decision. Therefore, in this paper we allow depositors to move sequentially. Empirical studies show that depositors' choices are sometimes observable and affect subsequent depositors' decisions. Grada and Kelly (2000), Iyer and Puri (2012), Iyer et al. (2016) and Atmaca et al. (2017) study observability in one's social network or neighborhood: observing that others withdraw (keep their funds deposited) increases (decreases) the likelihood of withdrawal. These studies suggest also that depositors observe withdrawals more broadly than holding funds in the bank.

Starr and Yilmaz (2007) show that in a bank run episode in Turkey in 2001 small and medium-sized depositors seemed to observe only their peers' withdrawals. Large depositors, however, also observed each other when opting to

[1] In all three cases, miscoordination and a liquidity crisis were accompanied by worsening fundamentals, triggering the breakdown of lending, finally leading to bankruptcy. Yet, nowadays, AIG is again a profitable insurer and Bear Stearns forms part of JP Morgan Chase, while Northern Rock was acquired by Virgin Money.

[2] A large part of the literature maintains this assumption (see, for example Ennis and Keister 2009a).

[3] This was the case, for example, during the silent run on Washington Mutual in 2008, when depositors withdrew their funds electronically.

keep their funds deposited. Since the large depositors generally observed no other large depositors withdrawing funds, they accounted only for a small share of total withdrawals. Observing each other helped large depositors to coordinate their actions and prevented them from running the bank. We introduce such a coordination device in the form of announcements. More precisely, in one treatment depositors are allowed to announce (at a cost) that they are keeping their money in the bank—a decision that cannot be observed otherwise. Our goal is to study the effect of such announcements theoretically and test experimentally whether they foster coordination on the no bank run equilibrium.

Experimental studies highlight the importance of observability as well. For example, Kiss et al. (2014a), Davis and Reilly (2016), and Kiss et al. (2018) find that observing a withdrawal (rather than not observing anything) increases the likelihood of withdrawal, while the opposite holds when observing depositors keeping their money deposited.

Hence, there is evidence that observing other depositors keeping their funds in the bank helps to prevent inefficient withdrawals and bank runs caused by a coordination failure among depositors. Yet, observing this decision is more difficult than observing withdrawals. Queues in front of banks or ATMs represent this kind of asymmetric observability: it is quite likely that those seen queuing are intending to withdraw. However, it is unknown whether those not in the line will keep their money in the bank or not. Thus, withdrawals are more visible and easier to interpret.

Taking these empirical observations into account, in our study in the benchmark case, depositors can only observe withdrawals. In our analysis we introduce the possibility of publicly revealing to subsequent depositors the decision to maintain one's funds deposited. Our goal is to study the effect of the enlarged strategy space on the likelihood of bank runs. Making public the decision to keep the funds in the bank is not standard practice in financial intermediation. Yet, recent technological advances may convert this theoretical idea into a practical tool. In our model, this tool allows depositors to announce publicly that they have kept their money in the bank. Similarly, in the experiment we allow the subjects to make an announcement when keeping their money deposited, while withdrawals are always publicly observable.

Shin (2009) identifies coordination failure of institutional investors as the main trigger of the bank run on Northern Rock, which possibly could have been prevented or mitigated by such a coordination tool. Both our theoretical and experimental results suggest that such a coordination device would have facilitated the coordination of investors in Northern Rock and other financial institutions on a concerted roll-over of the funding, thereby preventing a bank run.

In this paper we will not address the practical issue of designing and implementing such a tool for retail banks and investors. However, our results indicate that such a tool would be desirable since participants in our experiment used it eagerly: even though it did not prevent bank runs entirely as predicted by theory, it reduced their occurrence in the experiment. Therefore, regulators, banks and other financial institutions might want to consider this idea in order to improve coordination among depositors in times of uncertainty and partial withdrawals.

In our model depositors decide sequentially according to an exogenously given order.[4] A depositor withdraws, keeps the money deposited and makes this choice public, or keeps her deposits in the bank without announcement. Making public the decision to keep the money in the bank is moderately costly (capturing opportunity cost of time or money, or the direct cost of announcing this to the bank in a legally binding way), costless or even monetarily compensated (for example, when sight deposits are converted into term deposits, they earn a higher interest). Depositors may find it appealing even to pay for such an announcement if this dissuades subsequent patient depositors from withdrawing and thereby avoiding a bank run.

We will show that in this model making public the decision to keep the money deposited strictly dominates withdrawal in relevant information sets, for any patient depositor. Henceforth, patient depositors know that no other patient depositor will withdraw in these information sets, and all of them keep the money deposited. Given costly announcements, in the unique equilibrium outcome patient depositors would not announce their decision to keep the money deposited:[5] once all patient depositors have opted to keep their holdings in the bank and this is commonly known, all of them are better off saving the cost of making this public. Nevertheless, without this tool of publicizing the decision to keep the money deposited, there are multiple symmetric equilibria: apart from a no bank run equilibrium, there exists an equilibrium outcome in which patient depositors withdraw.

We test the theoretical predictions in the laboratory by designing two treatments: in the *baseline treatment*, subjects either withdraw (this action is observable by subsequent depositors) or not (which cannot be observed), and in the *public treatment*, subjects additionally can publicly announce (at a fixed cost) that they have opted to keep the money deposited. In this paper we implement the most stringent (positive cost) scenario in the lab, because paying a positive cost for the announcement is a credible and binding way to communicate one's decision to the other depositors. Moreover, a wide use of announcements would confirm our conjecture that subjects might be willing to incur (a small) cost to induce other depositors to keep their money deposited.

Our conjecture in this line was confirmed by the results. Depositors use the costly announcements more frequently than predicted by theory, but reassuringly, not in an indiscriminate way. We also find that observing announcement(s) increases the rate of keeping the money deposited.[6] In the experiment we observe that contrary to the theoretical prediction, withdrawal rates in the information sets that coincide

[4] This is a standard assumption in the literature: see Green and Lin (2000, 2003), Andolfatto et al. (2007), Ennis and Keister (2009b).

[5] If costs are zero or negative, in the unique no-run equilibrium outcome patient depositors would be indifferent between announcing or not, or would always announce their decision to keep the money deposited, respectively.

[6] Given our experimental results, we did not take the other two cases to the lab: since in the most stringent case, in which both monetary incentives and theoretical predictions point against the use of announcements, we observe their use so frequently, we are confident that in the other cases depositors would use them frequently as well. In both of them, the theory and a potential monetary gain support this decision and hence should generate the same positive effect on reducing the withdrawal rates and the frequency of bank runs.

in both treatments are not significantly different. Moreover, while theoretically we expect to observe no announcements, we find an extensive use of them in the lab. This in turn often translates into significantly lower withdrawal rates in information sets with announcements. Said announcements foster coordination on the no bank run outcome and our results show that this is effective: with announcements, the frequency of bank runs is significantly lower than without them, although the economic relevance is debatable.

Although publicizing does not pay off individually—in the lab the costs of the announcements were not compensated by the implied benefits of fewer withdrawals, it increases significantly the total payoffs in those situations since it induces other depositors not to withdraw. In these cases, earnings are higher (though sometimes only marginally) in the public treatment. Furthermore, our results show that bank runs are significantly more likely to occur in the baseline treatment without announcements, though the differences, while statistically significant, are rather small.

1.1 Related literature

The degree of observability is studied theoretically, for example, by Peck and Shell (2003) who assume that the bank only observes withdrawals.[7] In contrast, Green and Lin (2000, 2003) assume that each depositor contacts the bank and communicates her decision to withdraw or to keep funds deposited. We assume that withdrawals are observable (as in Peck and Shell 2003), while keeping the money deposited is not. However, following the idea of Green and Lin (2003) in our model keeping the money deposited can be made observable by the depositor at a cost.

Beyond the literature already mentioned, there are only few papers that assume sequential decisions of depositors. Ennis and Keister (2016) study such a setup with aggregate uncertainty about depositors' liquidity types. Bank runs may arise when the bank and depositors observe withdrawals sequentially. In a model without uncertainty regarding aggregate liquidity, Kinateder and Kiss (2014) assume that depositors decide sequentially and observe *all* previous choices before deciding. They study two setups: one in which the liquidity needs of previous depositors are observed, and another in which they are private information. In both cases, bank runs do not occur in equilibrium. These results suggest that sequential decisions may be successful in wiping out bank runs only in environments without aggregate uncertainty about liquidity needs.

In the experimental literature on bank runs, mainly simultaneous decisions have been studied to capture the coordination problem among depositors (see e.g. Arifovic et al. 2013).[8] Assuming fundamental uncertainty about the bank's health which is generally unobservable to depositors, Schotter and Yorulmazer (2009)

[7] Chari and Jagannathan (1988) show how a high withdrawal demand may be perceived incorrectly as a signal of the bank's poor quality.

[8] Brown et al. (2016) and Chakravarty et al. (2014) analyze whether bank runs are contagious if depositors can observe the decisions of other banks' depositors.

use simultaneous and sequential treatments and compare outcomes with different degrees of observability. They study how, for example, asymmetric information or deposit insurance affect the speed of withdrawals.[9] Theoretically, the behavior of subjects should not depend on the form of the game, yet the available information affects subjects' choices. Garratt and Keister (2009) forced part of the subjects to withdraw with some probability or gave subjects multiple opportunities to withdraw and informed them about any withdrawal. In this case, forced withdrawals combined with multiple opportunities to withdraw resulted in frequent bank runs. The authors claim that more information about other depositors' decisions may be harmful for coordination. However, none of these papers consider the asymmetry of available information in the way we do.

At the heart of our paper lies the assumption that a patient depositor can credibly reveal that she has opted to keep her funds deposited. In reality, the closest mechanism to this is to commit not to withdraw the funds by having a sight deposit converted into a time deposit, although this is (currently) not observable by other depositors.[10]

The paper proceeds as follows. Section 2 presents a theoretical example with predictions that we test in the lab. Section 3 presents the experimental design and Sect. 4 contains our findings. Section 5 concludes.

2 Intuition of the theoretical model

In this section we develop in detail a simple example (based on the theoretical model) that was implemented in the lab. This example illustrates the underlying intuition and helps to derive the hypotheses of our experiment. Section B in the Online Appendix contains the formal analysis of the theoretical model in a generalized setting with the equilibrium predictions and the corresponding proofs.

Suppose that there are three patient depositors (without urgent liquidity needs) and one impatient one who needs to withdraw the money from the bank. Liquidity type (patient vs. impatient) is private information. The number of patient and impatient depositors is commonly known. Following the literature (Diamond and Dybvig 1983; Green and Lin 2003; Ennis and Keister 2009a), we assume that there is no fundamental uncertainty about the return that the bank earns on its investments. Moreover, we let depositors decide sequentially: a decision-making sequence is the order in which the depositors decide if they want to withdraw their funds or keep them deposited and possibly announce this to subsequent depositors. In this example, there are four possible sequences, called type vectors (e.g., patient, impatient, patient, patient). We study the least informative case, that is, each type vector

[9] Kiss et al. (2012) and Madies (2006) also study the efficiency of deposit insurance to curb bank runs in laboratory experiments.

[10] Niinimäki (2002) proposes a model with time deposits in order to prevent bank runs. However, in his model, observability does not play any role.

is equiprobable. Once the type vector is randomly selected, each depositor observes her own type but not her or any other depositor's position in the queue.

We assume that all three patient depositors need to keep the money in the bank in order for this strategy to pay off for all of them. If a depositor keeps her funds deposited and including herself three, two, or one depositor(s) do(es) so also, then her payoff is 125, 70, or 70 experimental currency units (ECUs), respectively. A depositor who is the first, second, or third to withdraw receives a payoff of 100 ECUs, while if she is the fourth (i.e. last) to withdraw, then she earns 60 ECUs. In this case, after observing three withdrawals, a patient depositor is better off keeping her funds deposited since it accrues interest and yields 70 ECUs.[11]

We consider two cases: when keeping funds deposited can be made public and when it cannot. In Table 1 we summarize the payoffs of withdrawal and keeping the money in the bank given the other depositors' decisions. The announcement cost of 10 ECUs should be deducted from the last column if a depositor keeps her funds deposited and makes an announcement to that effect.

2.1 The case with announcements

A patient depositor may withdraw, keep her money in the bank, or keep her money deposited and announce it to subsequent depositors. Keeping the money deposited is only observable if it is announced at a cost of 10 ECUs.

Here, our goal is twofold. First, we show that the unique perfect Bayesian equilibrium of the game does not yield a bank run (of any severity, measured as the number of withdrawals by patient depositors). Second, we then provide an understanding of why the mere availability of public announcements eliminates bank run as an equilibrium outcome. A formal derivation of the results for any (positive, negative, or zero) fixed cost of announcement is relegated to section B of the Online Appendix.

We denote the decision to withdraw by *wi*, keeping the money deposited and making it public by k_p, and keeping the money deposited without announcing it by *k*. The best response as a function of the previously observed decisions, in the exact order of how they were observed, is denoted by $BR(\cdot)$. For example, $BR(k_p, wi)$ is the best response when a depositor observes that first, a depositor kept her money in the bank and announced it, and then another depositor withdrew her funds. However, since not all decisions are observable, the number of previously observed decisions does not necessarily reveal one's exact position in the queue. In this example, a depositor infers that she is third or fourth in the queue.

First, consider any information set that contains three previously observed choices. In these cases a patient depositor's best response is uniquely determined and it does not include the use of public announcements, since she knows with certainty that she is last in the sequence. In particular, if she observes that two depositors kept the money in the bank and one depositor withdrew, then the

[11] That the last depositor's dominant strategy is to keep her money in the bank is a feature of the Diamond–Dybvig model (see Ennis and Keister 2010) also present in other bank run models, such as, Green and Lin (2003).

optimal decision is to keep the money deposited without announcing it, earning herself 125 rather than 100 ECUs (corresponding to withdrawing).[12] Hence, $BR(k_p, k_p, wi) = BR(k_p, wi, k_p) = BR(wi, k_p, k_p) = k$. When she observes that two depositors withdrew and the other kept her money in the bank, then the best response is to withdraw, yielding a payoff of 100 instead of 70 ECUs (corresponding to keeping the money deposited). Thus, $BR(k_p, wi, wi) = BR(wi, k_p, wi) = BR(wi, wi, k_p) = wi$. The best response when observing three withdrawals is to keep the money deposited, i.e., $BR(wi, wi, wi) = k$, since it yields 70 instead of 60 ECUs (corresponding to withdrawal).

In the same vein, if a patient depositor observes that two depositors have kept their funds deposited, she will know that she is third in the queue and there is only one impatient depositor behind who will withdraw for sure. In this case, her best response is to keep the money deposited without announcing it, yielding the maximum payoff of 125 ECUs. Therefore, $BR(k_p, k_p) = k$.

Now, if a patient depositor observes two withdrawals, she knows that she is either third or fourth in the queue. In the case of being in fourth place, after two withdrawals (and one depositor who has eschewed withdrawal), the best she can do is to withdraw as this yields a payoff of 100 instead of 70 ECUs. If she were third in the queue, there might be a patient or an impatient depositor behind, but in any of the cases, at least one patient depositor in front will have withdrawn. Therefore, by keeping the money, the maximum payment to which she could aspire is 70 ECUs (or 60 if she also announces this), while withdrawing would yield 100 ECUs. We conclude that after observing two withdrawals, a patient depositor's dominant strategy is to withdraw, i.e., $BR(wi, wi) = wi$.

The four information sets that are left to analyze have no dominant strategy, yet the behavior in all of them is related. First, if a patient depositor observes that one depositor has kept the money in the bank (k_p), she infers that she is second or third in the queue.[13] In this case, withdrawing yields a payoff of 100 ECUs, independently of the decision of the subsequent depositor(s). If instead, she keeps the money deposited and announces this publicly, then she will earn 115 ECUs, because either there is no patient depositor behind her in the queue (i.e., she was third in the queue), or there is one patient depositor left (i.e., she was second in the queue) who observes the history (k_p, k_p) or (k_p, k_p, wi). As just shown above, keeping the money without making it public is the best response to any history that contains two announcements. Hence, in this case, our subject can be sure that the last patient depositor, by sequential rationality, will keep the money deposited. This means that keeping the money deposited and announcing it strictly dominates withdrawal given this history. Therefore, no patient depositor would withdraw after observing one announcement.

This result has strong implications for $BR(k_p, wi)$: after observing a history with one announcement and one withdrawal, a patient depositor infers that the withdrawal cannot be due to a patient depositor. As a consequence, a patient depositor

[12] Given the number of patient and impatient depositors, it is impossible that a patient depositor observes three depositors keep their funds in the bank.

[13] She cannot be fourth, as in that case she would have observed at least one withdrawal.

Table 1 Payoffs corresponding to the different decisions, depending on others' choices

Withdraw		Keep money deposited	
Number of *previous* withdrawals	Payoff	Number of *total* withdrawals	Payoff
0	100		
1	100	1	125
2	100	2	70
3	60	3	70

would rather keep the money in the bank and announce it than withdraw, earning 115 ECUs (vs. 100 ECUs). We can be even more precise in this case. If no patient depositor withdraws upon observing (k_p, wi), then there is no point in making a costly announcement, so $BR(k_p, wi) = k$. This would save 10 ECUs and the remaining patient depositor in the queue, if there is one, will also keep her deposits in the bank.

Given the previous reasoning, we can explain the best strategy of a patient depositor after observing nothing, i.e., $BR(\emptyset)$. Again, we will show that in this information set, keeping the money in the bank and announcing it dominates withdrawal. We saw above that any patient depositor upon observing k_p would not withdraw. On the other hand, the impatient depositor—independently of the history—always withdraws, and the subsequent patient depositor(s) would observe (k_p, wi). Finally, as just shown, $BR(k_p, wi) = k$. This implies as well that any history that starts with a depositor keeping the money deposited and announcing it, leads to an outcome in which no patient depositor withdraws. Hence, after not observing anything, keeping the money deposited and making it public yields, by sequential rationality, a payoff of 115 ECUs, while withdrawing would yield only 100 ECUs. Thus, keeping the money and announcing it dominates withdrawal.

An important consequence of the above reasoning is that if the first observed decision is a withdrawal, then any depositor will conclude that this corresponds to the impatient depositor. Given $BR(wi, k_p, k_p) = k$ and sequential rationality, a patient depositor will keep her funds deposited and announce it rather than to withdraw after observing a withdrawal followed by a depositor keeping funds in the bank (wi, k_p), as this will yield 115 instead of 100 ECUs. Moreover, if no patient depositor withdraws when observing (wi, k_p), then the best a patient depositor can do is to keep her funds without announcing it, so $BR(wi, k_p) = k$.

Again, as a consequence, upon observing one withdrawal, a patient depositor—attributing it to the impatient depositor—will prefer to keep her money in the bank and announce it to withdrawing. However, if no patient depositor withdraws upon observing a withdrawal, then there is no point in incurring the cost of announcement; it suffices if patient depositors keep their funds without announcing it, so $BR(wi) = k$. Overall, this implies that a patient depositor who does not observe any previous decision keeps funds deposited without announcing it, i.e., $BR(\emptyset) = k$.

For any type vector, as the game unfolds, no information set arises in which the patient depositor would withdraw her funds. Hence, no bank run emerges. Notice

that we do not claim that withdrawing the money is not the best response for some information sets, but we assert that such information sets do not arise in equilibrium by applying sequential rationality.

In order to see that any other strategy profile is no equilibrium, consider the following one that would lead to a bank run: a depositor withdraws after observing 0, 1 or 2 withdrawals and keeps the funds deposited otherwise. Is there a profitable deviation from this strategy? Assume that a patient depositor observes nothing and has to decide whether to follow the prescribed strategy profile or to deviate. Following the run strategy would yield 100 ECUs. Suppose that when no withdrawals are observed she deviates by keeping the funds deposited and making this public.[14] From the previous arguments we know that a patient depositor upon observing that a depositor has kept her funds deposited and announced doing so, is strictly better off keeping her funds deposited and announcing it rather than withdrawing, anticipating that the last patient depositor would follow suit.

Thus, if the deviating patient depositor is followed by an impatient depositor who withdraws, then by the previous arguments, the remaining patient depositors will identify this depositor as impatient, because a patient depositor upon observing k_p would not have withdrawn. Similar arguments apply to the last patient depositor, and in the end, no patient depositor withdraws after observing a history that starts with a deviation of k_p. Therefore, this deviation is profitable. Using best responses and the dominance argument it can be shown similarly, that no equilibrium strategy involving a patient depositor withdrawing can be constructed. Moreover, no announcement is observed in equilibrium.

2.2 The case without announcement

Next, we assume that keeping the money in the bank can neither be observed nor made public. Consider the previous case with four depositors, three of which are patient. It is easy to see that if depositors only observe withdrawals, then *keeping the money deposited when observing 0, 1 or 3 withdrawals and withdrawing otherwise* is an equilibrium that results in no bank run.

However, there exists another equilibrium, in which a bank run occurs, with the following strategies: *withdraw if observing 0, 1 or 2 withdrawals and keep the funds deposited otherwise*. It can be seen immediately that there are no profitable deviations from any of the proposed strategies. Hence, in this case, there are multiple equilibria. The lack of profitable deviations is due to the fact that deviations cannot be observed: if a patient depositor deviates, the other patient depositors will not notice it and will stick to the run strategy.

Summarizing, in the model where depositors can make public that they keep the money in the bank, there is a unique no-run equilibrium and announcements are never used. If only withdrawals are observable, there are multiple equilibria: besides the no-run equilibrium there exists a run equilibrium as well. Notice, that although

[14] If the patient depositor does not announce her behavior, then subsequent depositors would not observe it, and therefore, would not change their behavior.

this difference may affect the emergence of bank runs, no bank run is an equilibrium outcome in both models. In the next section we test our theoretical findings in the laboratory.

3 Experimental design and results

3.1 Procedure

We recruited a total of 150 subjects (76 female and 74 male) without previous experience in experiments on coordination problems or on financial decisions. We ran four sessions at the Laboratory for Research in Experimental Economics (LINEEX) at the Universidad de Valencia (Spain) in October 2015 and July 2017. On both dates, two treatments were implemented, one in each session: one corresponding to the baseline and another to the public treatment. The subjects were students from different disciplines at the university, of which only about 17% were studying Economics or Business.[15] No subject participated in more than one session (or treatment). The experiment was programmed using z-Tree (Fischbacher 2007). Instructions were read aloud at the beginning of each session and questions were answered privately. The experiment began once all participants had answered correctly three control questions regarding the experiment.

In the laboratory, a bank was formed by four depositors, each endowed with 80 experimental currency units (ECUs). Three of the depositors were participants in the lab (patient depositors), while the fourth, the impatient one, was simulated by the computer. We explained that the impatient depositor always withdraws and that a subject's payoff depends on her own and her co-players' decisions.

In both treatments, we used identical payoffs (see Table 1), and in the public treatment, participants could reveal at a cost of 10 ECUs to subsequent depositors that they are keeping their funds deposited, as in the example analyzed in Sect. 2. In the instructions (see section C in the Online Appendix) we pointed out that the subjects' position in the queue is unknown. The instructions also explained that subsequent depositors can observe withdrawals and, in the public treatment, also holding the money whenever this is announced. By means of examples, we illustrated that a given observation might be compatible with several previous decisions, and hence, reveal important information.[16]

We only test the case when making public the decision to keep the funds deposited has a positive cost. Based on the theoretical predictions, we conjecture that subjects would use announcements more intensively if costs were zero or negative. Therefore, if in the most stringent case—that is, with positive costs—patient

[15] On the first date, 25% of the participants were students majoring in Economics or Business, and on the second, this proportion was 12%. In section D of the Online Appendix we show in detail the composition of the subject pool.

[16] For example, observing nothing is compatible with being in positions 1, 2 or 3; but it is not compatible with being fourth in the queue.

depositors' withdrawals, and hence, the incidence of bank runs are significantly reduced, then we can conclude that it can be qualitatively appealing in all three cases. Moreover, the difference between the theoretical predictions of no announcements and the subjects' use of them is more striking in the case of positive cost.

In the experiments we use the strategy method and ask participants to decide in all possible information sets. This method allows us to capture nicely an important feature of our model: while depositors do not know their position in the queue, the decisions observed may reveal information about it. By asking subjects for decisions in all the positions they could occupy, we try to uncover their reasoning and prevent systematic mistakes. The use of the direct-response method might have led participants to make wrong inferences about their position in the queue, for example, based on the time elapsed before deciding or on the clicking sounds in the room. This would have contaminated the experiment. Moreover, the strategy method yields a large number of observations at a reasonable cost.[17]

Therefore, in the baseline treatment, subjects decide in four independent situations[18] if they want to withdraw or keep the money deposited. In the public treatment, they decide in five more situations,[19]—overall in nine scenarios—if they want to withdraw, to keep the money deposited, or to keep the money deposited and make it public. To avoid order effects, the different situations were displayed on the screen in a random order. At the end of each session, banks of four depositors (three participants and the computer) were formed randomly and anonymously. After determining the random order of the four depositors, the program calculated each participant's payoff, taking into account the submitted decisions for the relevant information structure.

Before finding out their earnings at the end of the experiment, subjects filled in a questionnaire so we have information about demographic and socioeconomic variables (sex, age, field of study, family income, trust in different institutions),[20] cognitive skills (using a new set of the cognitive reflection test, see Frederick 2005; Toplak et al. 2014), and overconfidence by asking the subjects how many of the cognitive reflection test (CRT) questions they thought they had answered correctly. When asking about their trust in various institutions, we were especially interested in their attitude towards banks. We suspected that participants who distrust banks may be more prone to withdraw, which would distort our analysis if not taken into account.

[17] Frequently, the strategy method is criticized since subjects decide in hypothetical situations, and thus, their choices resemble reality less than those under the direct-response method. Brandts and Charness (2011) find that generally there are no significant differences in the results using either method: if the strategy method detects a treatment effect, then this is detected by the direct-response method, suggesting that our design choice is appropriate. Although direct response has the advantage that through repetition subjects may learn to play optimally, as bank runs are rare events, learning is not a concern in our setting.

[18] Namely, after observing nothing, one, two, or three withdrawals.

[19] The same information sets as before, and additionally, after observing no withdrawal and one announcement, no withdrawal and two announcements, one withdrawal and one announcement, one withdrawal and two announcements and finally, two withdrawals and one announcement.

[20] Family income is measured on a 0–10 scale on which each point represents a range of income. Trust in the different institutions is measured on a 0–10 scale as well.

In the first two sessions, we measured risk attitudes by the Holt-Laury test (see Holt and Laury 2002), but as reported in the literature (see Crosetto and Filippin 2016), there were many inconsistent choices (e.g., switching more than once or from the more risky to the safer lottery). Seemingly, many (certainly more than the average 15% reported in Crosetto and Filippin 2016) subjects mixed up their choices.[21] Given the low number of valid observations, we omit risk aversion from the analysis of the first two sessions.[22] In the last two sessions, following Sutter et al. (2013), we use a variant of Ellsberg (1961)'s two-color choice task to measure risk aversion.[23]

Each session lasted approximately one hour. In the first two sessions, the subjects received on average 10.64/11.8 Euros in the baseline/public session, including a show-up fee of 1 Euro. In the other two sessions, the subjects earned 12/11.9 Euros, respectively, including the same show-up fee. For the payment, ECUs were transformed into Euros using the exchange rate of 1 Euro for 10 ECUs.

3.2 Conjectures

To determine whether an option to make costly non-withdrawal announcements affects the emergence of bank runs, we compare the probability of withdrawals in both treatments. A bank run occurs if at least one patient depositor withdraws. The number of patient depositors who withdraw determines the severity of the bank run. If we observe fewer withdrawals, and hence, fewer bank runs (of any severity) in the public treatment, then we conclude that making public the decision to keep the money deposited is effective.

Conjecture 1 (withdrawals and likelihood of bank runs) *Fewer bank runs will occur in the public treatment than in the baseline treatment.*

Conjecture 1 is milder than the theoretical prediction according to which we should not see any withdrawal by patient depositors and no bank runs in the public treatment. On one hand, this theoretical prediction relies on standard rationality arguments: each depositor is fully rational and believes the others to be so as well. Deviations from full rationality in experiments are frequent, and in our case, may lead to withdrawals. For this reason, we collected data on cognitive skills. On the other hand, there might be no big differences in withdrawal rates/bank runs across treatments, because no withdrawal (and consequently no bank run) is also an equilibrium outcome in the baseline treatment. Moreover, the incidence of withdrawals and bank runs has direct consequences for the payoffs. Without withdrawals by

[21] Only 5/11 out of the 33 subjects in the baseline/public treatment start by choosing the less risky option and switch once to the more risky one as its expected value increases.

[22] In a similar experiment, Kiss et al. (2014b) find that risk aversion does not help to predict depositors' decisions.

[23] In this task, there is an urn with 10 black and 10 red balls. Subjects are endowed with money and bet on one of the colors. If it matches that of a randomly drawn ball, the subject earns 2.5 times her bet, and otherwise loses it. The amount of the bet placed naturally measures risk aversion: the less a subject bets the more risk-averse she is.

patient depositors, and therefore, no bank runs, we expect larger payoffs, both individually and on aggregate (bank) level.

Conjecture 2 (use of announcements) *No patient depositor will make a costly announcement of her decision to keep funds deposited.*

Conjecture 2 captures the theoretical prediction, that the mere existence of the announcements should suffice to wipe out bank runs. If we relax the assumption that depositors are fully rational, then we may observe some announcements.

4 Experimental results

First, we provide some descriptive statistics about withdrawal decisions. Since there is no significant difference in the observable characteristics of the subjects across dates in the treatments, and the Kolmogorov-Smirnov test fails to detect any significant differences in the distribution of decisions in any of the information sets of the two treatments across dates, we pool the data of the same treatments and present them in Table 2.[24][25]

There are four information sets that coincide in both treatments and can be compared directly. The corresponding decisions are represented in the first four lines of Table 2. Given the payoffs, after observing two withdrawals, a patient depositor's dominant strategy is to withdraw (and earn 100 instead of 70). In a similar vein, after observing three withdrawals, it is a dominant strategy for her to keep her funds deposited (and earn 70 instead of 60). While these information sets allow us to infer whether subjects make the optimal decision when it is available, we are mainly interested in the information sets when nothing or one withdrawal is observed which are present in both treatments. Since these information sets materialize at the beginning of the sequence of decisions, they are key to understanding why bank runs arise.

First we analyze whether the data confirm Conjecture 1. Table 2 reveals minor differences in the withdrawal rates in the coincident information sets. This suggests that the observational asymmetry does not affect depositors' decisions in these information sets.

Result 1 (withdrawal rates) *The availability of announcements does not lead to significantly different withdrawal rates in the information sets that are common in the two treatments.*

Statistical evidence For each shared information set, we separately test the null hypothesis that withdrawal rates are equal against the alternative that withdrawal

[24] Section D in the Online Appendix contains the results of randomization.

[25] When we pool non-withdrawal decisions, the test of proportions and the Wilcoxon ranksum test reveal significant differences in two of the nine information sets. For details, see section E in the Online Appendix.

rates in the baseline treatment are higher. The test of proportions fails to reject the null hypothesis for any of the four information sets (p value > 0.37 in all cases).[26]

Note that in the public treatment according to the theoretical prediction the frequency of non-withdrawals should be 100% for the first two information sets in Table 2. The predictions are based on the common knowledge of rationality. It may be violated at least in two ways. On the one hand, participants may not be fully rational. On the other hand, even if a participant is fully rational, she may doubt about the rationality of the other participants. Next, we investigate briefly these two possibilities.

In order to assess the participants' rationality in the experiment, we check whether they choose the dominant strategies in the information sets in which they exist. Withdrawing is a dominant strategy after observing two withdrawals, and indeed, this information set has the highest withdrawal rate in both treatments. After three withdrawals, keeping the money deposited is strictly dominant and the withdrawal rate in this case turns out to be the lowest in both treatments. 52% of the participants chose the dominant strategy in both cases and only 6% never did so. Hence, 94% of the participants is at least partially rational.[27]

Doubting about the rationality of the other participants is akin to being uncertain about how those co-players will play, so it can be viewed as a case of strategic uncertainty. If a participant does not believe that the other participants understand that withdrawal is a dominated action, and moreover, no announcement should be made in the first best, then she might decide to use announcements or simply withdraw and secure a sure payoff of 100. As an extreme case, assume that a participant who decides upon observing nothing, believes to be in position 1 and that the other patient depositors in the bank decide randomly between withdrawing or keeping their funds deposited. In this case, withdrawal is a best response if $u(100) > \frac{1}{4}u(125) + \frac{3}{4}u(70)$. Hence, even if every participant is fully rational but there is uncertainty about the rationality (and therefore the choice) of other participants, we may observe frequent withdrawals in information sets characterized by strategic uncertainty. The mere availability of public announcements does not help to overcome this problem. However, the actual use of announcements may help, as it reveals clearly that a patient depositor has kept her money in the bank, eliminating strategic uncertainty about her choice.

Table 2 highlights the importance of announcements. Our findings about the use of announcements are summarized in Result 2.

Result 2 (use of announcements and withdrawals) *When comparing information sets that only differ in observing announcements, we find that withdrawal rates are always lower in those that include announcement(s). These differences are significant when information sets differ in two announcements, but generally fail to be significant if the difference is only one announcement.*

[26] In section E in the Online Appendix, we repeat the same analysis for the two dates separately and report very similar results.

[27] In section F of the Online Appendix we provide a more thorough analysis of rationality.

Table 2 Breakdown of non-withdrawal decisions in each information set in both treatments

Observed decisions	Baseline treatment frequency of non-withdrawals (%)	Public treatment frequency of non-withdrawals (%)	of which: announcement (%)
Nothing	69.3	66.7	36.0
1 Withdrawal	45.3	48.0	25.0
2 Withdrawals (wi)	33.3	28.0	4.6
3 Withdrawals (k)	77.3	78.7	3.4
1 Withdrawal, 1 announcement	–	58.7	29.6
1 Withdrawal, 2 announcements (k)	–	89.3	23.9
2 Withdrawals, 1 announcement (wi)	–	33.3	27.9
1 Announcement	–	72.0	55.6
2 Announcements (k)	–	86.7	27.7

The notation (wi)/ (k) in the first column denotes that the dominant strategy is to withdraw/ keep the money deposited after the given observations

Statistical evidence To assess the importance of announcements, we compare the withdrawal rates in the five information sets that differ only in the observation of announcement(s).[28] We carry out two sorts of comparisons. First, we use all the observations (pooling data from the baseline and the public treatments) to compare information sets with and without announcements. Second, we restrict our analysis to the public treatment and carry out the previous comparison only for observations from this treatment.

Withdrawing is a dominant strategy in both treatments for the information sets with two withdrawals or with two withdrawals and one announcement. Hence, in the comparison of these information sets announcements should not matter. Our data confirm this, as the two-sided test of proportions fails to detect any significant difference in any of the two comparisons (p values > 0.47 in both cases). When comparing the information sets nothing vs. one announcement, the withdrawal rate is lower in the information set with one announcement but the difference is not significant (two-sided test of proportions, p values > 0.47 in both cases). The comparison between one withdrawal vs. one withdrawal and one announcement does not yield a significant difference when considering only the public treatment (two-sided test of proportions, p value $= 0.19$), but a weak significant difference with the expected sign (two-sided test of proportions, p value < 0.09), if we consider observations from the baseline treatment as well.[29] When

[28] These are the following: (1) nothing versus one announcement; (2) nothing vs. two announcements; (3) one withdrawal versus one withdrawal and one announcement; (4) one withdrawal versus one withdrawal and two announcements; (5) two withdrawals versus two withdrawals and one announcement.

[29] If we apply a one-sided test, assuming that withdrawal rates are lower in the presence of the announcement, then the p values are halved and we have (at least weak) significant differences in both cases.

comparing the information sets nothing vs. two announcements, and one withdrawal vs. one withdrawal and two announcements, then withdrawal rates in the latter cases are considerably lower. Indeed, in all cases, using the two-sided test of proportions we find a significant difference at the 1% level.

Based on the theoretical results for the public treatment, Conjecture 2 predicts that patient depositors should neither withdraw nor use announcements. However, in the laboratory we find that depositors use announcements actively. Overall, this indicates that in the lab it is not the *availability* of announcements *per se* that matters, but it is its active use that leads to fewer withdrawals, and therefore, to fewer bank runs. This is in line with our previous reasoning that announcements are used to dissipate strategic uncertainty. Once such uncertainty is eliminated (that is, two announcements are observed) withdrawal rates drop considerably.

Result 3 (use of announcements) *Depositors make costly announcements more frequently than theory predicts.*

Statistical evidence The third column in Table 2 shows the frequency of non-withdrawals for the different information sets in the public treatment, and the last column contains the relative use of announcements. When two or three withdrawals are observed and the corresponding dominant strategies (withdrawal and keeping the money in the bank without announcing, respectively) are unique and do not include the use of announcement, these are hardly ever used. In the pooled data, at the 1% and 5% significance levels, zero (i.e., using no announcement) is included in the confidence interval if two or three withdrawals are observed. Hence, in these cases we cannot reject the null hypothesis that the probability of using announcements is zero.

At the 99% confidence level, in the other information sets, the probability of using announcements is significantly positive for the pooled data. Contrary to the theoretical prediction, participants use announcements actively. However, its frequency tends to decrease with the number of observed decisions. This suggests that subjects use announcements as an instrument to *induce* subsequent patient depositors not to withdraw, by decreasing/eliminating strategic uncertainty.

In general, the rate of announcements is lower than that of just keeping the funds deposited (that is, the percentage in the last column in Table 2 is less than 50%) and the difference is significant at the 5% level according to the test of proportions (except when one announcement is observed, p value > 0.3). This indicates that despite being used extensively, announcements are still used less frequently than keeping the money in the bank without announcement.

To provide further evidence on the effect of the availability and use of announcements, we run linear probability regressions both with and without individual characteristics gleaned from the questionnaire. We relegate the detailed analysis to Appendix A, and summarize here the main findings. Withdrawal rates drop significantly, *ceteris paribus*, when at least two announcements are observed. When the effect of announcements is significant, the probability of withdrawal decreases by 20–23 percentage points, *ceteris paribus*. Similar to the

results seen before, the information sets with one announcement do not have a significant mitigating effect. These results are in line with our previous conclusions: the availability of announcements changes only slightly the behavior in the information sets that coincide in both treatments, but it does have a large effect on creating information sets that contain announcements. This indicates to subsequent depositors that previous depositors have kept their money in the bank. None of the individual characteristics that we consider affect significantly the withdrawal decisions.

Although announcements should never be used according to theory, empirically this improves efficiency if the overall payoffs are larger when announcements are used. As indicated before, participants are not fully rational, and moreover, might not be sure how (ir)rational their co-players are. Therefore, they may use announcements to ensure that others do not withdraw either. If this convinces a subsequent participant not to withdraw, then it is a welfare-enhancing decision. To see whether announcements have such beneficial effects, we calculate the expected payoffs forming all possible banks, following the method of recombinant estimation.[30]

In Table 3, we restrict our attention to the information sets without a dominant strategy (where a persuasive announcement may result in larger payoffs). We observe that the use of announcements does not increase the average expected individual payoff in those information sets. Making public the decision of keeping the money in the bank increases significantly the expected total payoffs—in a statistical sense—in 3 out of 4 cases. Hence, the use of announcements is efficient from a social point of view. However, the economic significance is only meaningful (8.7–9.6 ECUs, about 3% of the total payoffs) in half of the cases (when nothing/an announcement is observed). If we analyze the distribution of payoffs, taking into account all information sets and decisions (i.e., the ones with a dominant strategy as well), then expected total payoffs in the baseline treatment (382.1) are higher than in the public one (380.2), due to the irrational overuse of announcements. Again, the difference is statistically significant, but economically less relevant.

The recombinant method also allows us to study the incidence of bank runs. A bank run occurs if, besides the impatient depositor, at least one of the patient depositors withdraws her money.

Result 4 (likelihood of bank runs) *In the public treatment the frequency of bank runs is lower than in the baseline treatment. Hence, the availability (and eventually the use) of announcements reduces the likelihood of bank runs, though the economic relevance is questionable.*

Statistical evidence In the public treatment, the frequency of no bank runs (when none of the patient depositors withdraws) is 22.13% while in the baseline treatment, without the existence of announcements, the same frequency is 21.21%. Although the magnitude of the difference is small, and therefore, the

[30] For details see Mullin and Reiley (2006) and Abrevaya (2008). We relegate the details of the computation to the section H in the Online Appendix.

economic importance of this finding seems to be limited, the chi-square test indicates that the difference between treatments is statistically significant (p value $<$ 0.001).

5 Conclusion

In this paper, we investigate the asymmetry in the observability of depositors' decisions: as shown in several empirical studies, withdrawals are more easily observed than keeping the money deposited in the bank. Earlier theoretical results indicate that if all previous decisions could be observed, then no bank run based on depositors' mis-coordination should arise in equilibrium. Hence, we set up a model in which withdrawals are always observed, while keeping the money deposited is not. Yet, we give depositors the opportunity to decrease this asymmetry in observability by allowing those depositors who keep their funds deposited to make this decision visible at a cost. Theoretically, depositors without urgent liquidity needs should not withdraw in this case, so a bank run is no longer an equilibrium outcome. Moreover, depositors should never use announcements, as their mere availability suffices to eliminate bank runs.

We test these predictions in the lab. In the baseline treatment, depositors decide whether to withdraw or not, with the first choice being observable, while the second not. In the public treatment, depositors may make public their decision to keep the money in the bank at a cost. Our results indicate that it is not so much the availability of announcements that is important—withdrawal rates are not significantly different in information sets that are common in both treatments—but its use. Namely, announcements indicate that previous depositors have kept their funds in the bank. As a consequence, subsequent depositors are more likely to keep their funds deposited as well, and withdrawal rates are lower in information sets that contain announcements, the difference often being significant.

We interpret the extensive use of announcements as the depositors' desire to coordinate on the no bank run outcome and our results show that this is effective: in the public treatment, the frequency of bank runs is significantly lower than in the baseline treatment (though admittedly the difference is rather small). We also find that using announcements compared to simply keeping the money in the bank does not pay off individually when accounting for the costs of doing so. However, total payoffs frequently increase significantly. It should be noted that while the difference is significant in a statistical sense, its economic relevance seems to be less pronounced. Further research is needed to shed light on whether depositors' desire to coordinate yields more efficient outcomes in an economically meaningful sense. Based on our theoretical results and the experimental findings, we answer the question posed in the title. Theoretically, depositors would like to have the opportunity to show others that they do not withdraw, but they would never actually do so if it were costly. The experiment suggests that depositors would not only like to have the opportunity, but they would use it extensively even if it had a (relatively small) fixed cost.

Table 3 Expected individual and total payoffs (pooled data) conditional on keeping the money or announcing in different information sets

Information set	Average individual payoff		Average total payoff	
	Keep	Announcement	Keep	Announcement
Nothing	91.74	90.91	297.11	305.82
1 Withdrawal	88.06	82.92	291.16	290.67
1 Announcement	112.33	110.16	331.94	341.51
1 Withdrawal, 1 announcement	110.43	104.77	328.63	328.97

In the total payoffs only the payoffs of the patient depositors are considered

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