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Born to Run: Adaptive and Strategic Behavior in Experimental Bank-Run Games *

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Abstract

We run a laboratory experiment to investigate how the size of the group affects coordination in a bank-run game played repeatedly by participants facing different fellow depositors. For comparability purposes, we keep the coordination tightness constant across different sizes. Participants exhibit an adaptive behavior, since the main drivers of their decisions to withdraw are: previous-round outcomes and own initial choice. Moreover, they mainly adopt the best response to previous-round feedback. However, a sizeable share of participants adopts the opposite mode of behavior, that we refer to as experimentation. The analysis of the determinants of experimentation suggest that subjects adopt this behavior when the probability to lead the group toward the efficient outcome is higher. Finally, our analysis shows that the size of the bank has a significant effect on participants' decisions, since they withdraw more and experiment less in large banks.

JEL Classification: C70, C92, D80, G21.
Keywords: Coordination Games, Experimental Studies, Bank Runs.

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1 Introduction

Bank runs can arise as a coordination problem among depositors, making the service that allows better risk sharing among people with different consumption horizons vulnerable to events that could negatively impact the economy by undermining the stability of financial system. Bank runs are a common feature of banking crises. Laeven and Valencia (2020) report that Argentina experienced system-wide runs in the crisis of 2001 and that banking panics were a common occurrence in the United States in the late nineteenth and early twentieth centuries, as well as in the Great Depression and during the financial crisis of 2008.

We use a controlled laboratory experiment to investigate how the size of the (stylized) bank affects individual withdrawing decisions and hence coordination among depositors. In the experimental frame, participants act as depositors and decide whether to withdraw or not an (indivisible) financial endowment from a bank. Following Diamond and Dybvig (1983), we setup a coordination game with two pure strategy Nash equilibria: one in which all depositors do not withdraw and another one in which they all withdraw and induce a run on the deposits of the bank. The first (second) equilibrium is supported by beliefs that no one (everyone) else will withdraw and it is Pareto (in)efficient.

We are interested in investigating individual behavior in a setting in which participants play the bank-run repeatedly with different fellow depositors. In this context, repeated game effects are weaker and it is not a priori obvious whether and how participants can coordinate on one of the equilibria. Yet our stylized setting seems suitable for the analysis of the stability of financial intermediaries, such as banks, in which the pool of depositors may change across time.

These two characteristics, namely the analysis of the size of the bank and interacting in different groups across time, constitute the original features of our design which allow to provide new evidence on behavior of subjects under strategic uncertainty in groups of different sizes.

In our experiment, participants play the bank-run game repeatedly, i.e., for several rounds. According to the evolutionary approach of Temzelides (1997), under myopic behavior the equilibrium dynamics of aggregate withdrawals exhibit two steady states qualitatively similar to the static equilibria. The watershed between these steady states is the share of withdrawals which makes depositors indifferent between their two choices, i.e., the *coordination parameter* in the terminology of Arifovic et al. (2013). In the experiment, we implement the random stranger protocol and consider three bank sizes, with five, seven and ten depositors, respectively. To compare behavior across bank sizes, we follow Arifovic et al. (2013) and impose the same coordination parameter for all groups. Moreover, we select its value in the region where Arifovic et al. (2013) observe no systematic convergence to either of the equilibria.

We investigate individual choices and focus on two modes of behavior based on different reactions to feedback information about previous-round outcome: the *adaptive behavior*, which assumes that participants best-respond to choices of fellow depositors in the previous round; and *experimentation behavior*, which assumes that participants experiment with the choice that was not their best response in the previous round. Furthermore, we study whether or not the size of the bank affects these behaviors.

We find that, regardless the size of the banks, withdrawal rates are around 40% in the first round and increase steadily with repetitions, what leads to universal withdrawing in the final rounds. Our analysis confirms that participants exhibit adaptive behavior, since their expectations are correlated with the feedback about previous-round outcome and their withdrawal decisions are consistent with these expectations. Moreover, the size of bank has a significant effect on withdrawal decisions, since the probability to withdraw is higher in large groups.

Our results also show that experimentation is sizeable, it is more frequent in earlier rounds and it decays with repetitions. Furthermore, it is more likely in smaller banks. Given the predominance of withdrawal decisions, we mostly observe experimentation with not withdrawing. Moreover, the probability to experiment is higher when the previous-round outcome is closer to the coordination parameter and subjects expect less withdrawals. These findings are consistent with the idea that subjects experiment when it is more likely to succeed in leading the group toward the efficient equilibrium and when failing in this attempt is expected to be less costly, since the payoff from not withdrawing is lower the higher the number of withdrawals. Therefore, we interpret our results as evidence of *strategic* experimentation.

In the experiment, we also provide to participants information about fellow depositors' financial literacy or general knowledge, elicited via an incentivized pre-test. Since our interest is in adaptive and experimentation behavior, we do not systematically investigate the relevance of these public signals for the coordination of depositors' choice. However, we use this information in the regression analyses as controls for the individual choices.

The paper is organized as follows: the related literature is discussed in Section 2; the theoretical benchmark is described in Section 3, the experimental protocol in Section 4 and our hypotheses in Section 5; Section 6 presents the econometric strategy while Section 7 the main results; Section 8 concludes.

2 Related Literature

Experimental analyses of bank runs mostly attempt at explaining the determinants of the choice of withdrawal and of the coordination on the inefficient equilibrium which identifies a bank run.[1] These two results are robust to several alternative specifications of the experimental protocol featuring, for example, sequential withdrawals (Kiss et al. 2012, 2014), aggregate uncertainty and multiple withdrawal opportunities (Garratt and Keister, 2009), suspension of deposit convertibility (Madiès, 2006) or deposit insurance (Madiès, 2006 and Schotter and Yorulmazer, 2009). A systematic investigation of the determinants of bank run, proposed by Arifovic et al. (2013), has identified the tightness of the coordination problem as a fundamental factor affecting subjects' behaviors. The severity of coordination is there measured by the coordination parameter, i.e. the threshold share of withdrawals that makes withdrawal the depositor's best response given the behaviors of his fellows. The higher is the value of the coordination parameter, the less severe the coordination on the efficient equilibrium. By letting the coordination parameter vary, Arifovic et al. (2013) identify three regimes: a first one, in which the coordination parameter is low, so that few withdrawals are sufficient to make withdrawal the preferred choice of a depositor, and bank runs dominate; a second one in which the coordination parameter is high and the experimental economies stay close or converge

[1] See Dufwenberg (2016) and Duffy (2016) for a recent survey

to no-run equilibria. A third regime, in which the coordination parameter assumes intermediate values and outcomes are indeterminate. This research builds on Arifovic et al. (2013) and analyzes the determinants of depositors' decisions in groups that have the same coordination tightness but different size. Specifically, our experiment features an intermediate value of the coordination parameter, for which Arifovic et al. (2013) have no clear predictions on agents' coordination outcome, and groups of size 5, 7 and 10 depositors, for comparative purposes.

In dealing with group's dimension, our design also relates to Garratt and Keister (2009), who examine banks constituted by 5 depositors, the smallest group we consider. In the withdrawal game of Garratt and Keister (2009), the coordination parameter is very high, since withdraw is a best response when at least four out of five depositors choose it, and a depositor's payoff is largely independent of fellow depositors' choices. They find no evidence of bank run in the baseline treatment, while runs emerge when aggregate uncertainty and multiple withdrawal opportunities are added to the experiment. Our experiment also indirectly tests the robustness of Garratt and Keister (2009)'s results to a different intensity of the coordination problem. In our data, a high frequency of withdrawal choices emerges from the very first round of the experiment even in small groups, and convergence to (almost) universal withdrawals is a persistent result.

The effect of group size on efficient coordination has been investigated in experiments on order-statistics games. In minimum-effort games, there is evidence that large groups fail to coordinate on the Pareto-dominant equilibrium.[2] However, in those games the efficient equilibrium is extremely fragile since individual deviations destabilize it, as observed by Crawford (1991). Median-effort games increase the robustness of the efficient equilibrium, because individual deviations may not destroy the subjects' coordination and inefficient coordination appears less frequently (see Huyck et al., 1991). When the coordination parameter of our bank-run game is at its lowest possible value, so that it is a best response to withdraw when just a single depositor chooses it, the game we study shares the same fragility of a minimum-effort game.

In dealing with the dynamic analysis of subjects' decisions, we build upon the theoretical work of Temzelides (1997) who considers a repeated version of Diamond and Dybvig (1983) to study the convergence properties of an economy populated by depositors with adaptive behavior. Temzelides (1997) shows that the Pareto efficient equilibrium is the basin of attraction of the dynamical system of depositors' strategies when it is also the risk dominant equilibrium of an economy with a single bank. In economies with multiple banks, he provides conditions for a local bank run to propagate among banks and generate a systemic run (universal withdrawal), when all depositors share the same history. In our setting, depositors only receive feedback about the withdrawal decisions at their own bank in every round, hence over time they do not share a common history. We test whether in each round a depositor chooses the action that would have performed best in the previous round, i.e. the $(t-1)$-best response, or her behavior encompasses some form of experimentation. Arifovic et al. (2013) provide a first attempt at analysing the determinants of the non-adaptive component of depositor's behavior in an economy with a single bank. We extend the analysis of experimentation to settings with multiple banks, of different dimensions, and highlight new strategic determinants.

[2] See Van Huyck et al. (1990) and Ochs (1995) and Camerer (2009, Ch. 7) for a review.

3 The Theoretical Benchmark

We consider a bank-run game inspired by Diamond and Dybvig (1983). Following their approach, banks are prone to runs because, despite the fact that they are financially sound, they may become illiquid if too many depositors (simultaneously) withdraw their deposits. To model this feature game-theoretically, we let depositors take a binary simultaneous choice upon whether or not to withdraw their deposits at the bank. In such bank-run game, the no-run and the bank-run scenarios correspond to the two (pure strategy) Nash equilibria.

To this end, we consider a group ("bank") of players ("depositors"). Depositors are assigned a deposit in the bank and choose either to withdraw ("w") or not withdraw ("n"). As it is typical in strategic interactions, the payoff from one's choice also depends on what other depositors do. In order to capture some salient features of the approach by Diamond and Dybvig (1983), we assume that (i) the payoff from not-withdrawing is greatest when all depositors choose n and decreases with the number of withdrawals; (ii) the payoff from choosing w remains (almost) constant as the number of withdrawals increases. Along the lines of Diamond and Dybvig (1983), the bank can invest its deposits in financial assets, and promises to each depositor a safe return R at maturity, and a return $1 \leq r < R$ in case of premature liquidation. Hence, the above assumption (i) mimics the feature that withdrawals trigger costly premature liquidation of the banks' long-term assets. Therefore, when some depositors withdraw, less resources remain available for those who don't because of foregone returns and liquidation costs. Condition (ii) instead mimics the feature that the bank accommodates withdrawals whenever possible so to maintain the promise to repay r; only if *too many* depositors choose w, financial resources are depleted and it is not possible for the bank to keep her contractual promise.

The actual payoff structure of our game is described as follows: let N denote the number of depositors and let each depositor have 1 unit of numeraire deposited at the bank, so that N is also the total value of the bank's deposits. Let μ_w and μ_n, with $\mu_w + \mu_n = N$, be the number of depositors who withdraw and do not withdraw, respectively. Given μ_n, μ_w, let $\pi_n = \pi(n|(\mu_n, \mu_w))$ and $\pi_w = \pi(w|(\mu_n, \mu_w))$ denote the individual payoff from n and w, respectively. Furthermore, let $0 \leq c, \gamma < 1$ be scale parameters, which can be interpreted as the cost of managing financial investments and the default cost, respectively.[3] In the experiment, we assume that:

$$\pi_n = \left\{ \frac{RN - R(r\mu_w)}{\mu_n} - c \quad \text{if } 0 < \mu_n \leq N. \right. \tag{1}$$

and

$$\pi_w = \begin{cases} \min\{r, N/\mu_w\} & \text{if } 0 < \mu_w < N, \\ 1 - \gamma & \text{if } \mu_w = N. \end{cases} \tag{2}$$

These values are interpreted as follows: the bank invests its resources and distributes the returns to depositors. If no one withdraws, the total return is RN. Since this is shared equally among all

[3] In the experiment we let the financial cost be borne by depositors who do not withdraw, except in the default case, when every depositor incurs a net loss in the nominal value of its deposits. This is not a crucial assumption, the payoff matrices could have been designed under the assumption that depositors who withdraw bear a liquidation cost.

depositors, we have a individual net return of $R - c$ when $\mu_w = 0$ and $\mu_n = N$. If $0 < \mu_w < N$ depositors withdraw, the amount $r\mu_w$ must be liquidated to repay the withdrawers and the return of the investment of the bank is reduced by $R(r\mu_w)$. The remaining capitalized investment $RN - R(r\mu_w)$ is shared equally among the depositors who do not withdraw, i.e. μ_n, who also pay the per-capita financial cost c. To the depositors who withdraw, the return r is guaranteed as long as $r \leqslant N/\mu_w$. This means that if *too many* depositors withdraw the premature liquidation of the total assets may yield the bank lower resources than those necessary to fulfill the promised return r. If this is the case, each withdrawer only gets an equal fraction of the resources available N/μ_w. When all depositors withdraw, $\mu_w = N$, all resources are liquidated and shared equally among depositors net of a default cost γ. Therefore, $\pi_w = 1 - \gamma$ when $\mu_w = N$. Depositors at a bank play a simultaneous-move game which exhibits two pure-strategy Nash equilibria: one in which no depositor withdraws and the bank is solvent; the other in which all depositors withdraw and a run on bank's deposits realizes. This second equilibrium is Pareto dominated and yields an inefficient outcome. Consistently with the approach of Diamond and Dybvig (1983), in the bank-run game bank run emerges as the result of coordination on an inefficient equilibrium when each depositor expects all others to withdraw.

When depositors play the bank-run game repeatedly, their strategies constitute a dynamical system, in which previous outcomes affect current decisions. Depositors react to observed withdrawals in the previous round, thus determining the bank's (il)liquidity in the current round. In this framework, Temzelides (1997) assumes that depositors act myopically and choose the best response to the withdrawals in the previous round. With such myopic behavior, the equilibrium dynamics of aggregate withdrawals exhibits two steady states:[4] in one of them, no depositor withdraws and banks remain solvent; in the other, every depositor withdraws and banks incur a run. The watershed between these two equilibria is the fraction of withdrawals (hereinafter $\tilde{\mu}_w$) which makes depositors indifferent between no-withdrawing and withdrawing; in the terminology of Arifovic et al. (2013), such threshold is the *coordination parameter*. This coordination parameter will be relevant in the experimental design, since, in line with our research questions, it will ensure comparability of outcomes in bank of different sizes.

4 The Experimental Protocol

In the experiment, we consider three bank sizes, namely with $N = 5, 7, 10$. Furthermore, we assume that $R = 1.6$, $r = 1.22$, $c = 0.1$ and $\gamma = 0.1/N$ and that each deposit is worth 100 units of numeraire. Table 1 summarizes the payoffs from withdrawing and from no-withdrawing when $N = 5$ as were shown to participants.[5] It is apparent that there are two (pure strategy) Nash equilibria for the bank-run game, namely all depositors choose n and all depositors choose w (the same occurs when $N = 7$ and when $N = 10$). The second equilibrium supports an inefficient outcome.

For comparability purposes, we use the same coordination parameter $\tilde{\mu}_w = 35\%$ in small, medium and large banks.[6] Because of the strategic complementarity between the choices of depositors, when

[4]Specifically, Temzelides (1997) shows that both equilibria are basins of attraction of the dynamical system representing the evolution of withdrawal choices.

[5]The payoff table when $N = 7$ and $N = 10$ are reported in Appendix A.

[6]We selected this value, since Arifovic et al. (2013) have shown it is not associated to systematic convergence to

Table 1: Payoff table for banks with $N = 5$.

	Payoff if you withdraw ○	Payoff if you do not withdraw ●
○ ○ ○ ○	98	7
● ○ ○ ○	122	90
● ● ○ ○	122	117
● ● ● ○	122	132
● ● ● ●	122	150

the fraction of depositors who withdraw is less than $\tilde{\mu}_w$, choosing n results in larger payoff than choosing w, while the opposite occurs when more than $\tilde{\mu}_w$ of depositors withdraw (see (1) and (2)). For instance, given Table 1 and $\tilde{\mu}_w = 35\%$, in small banks if the number of opponents' withdrawal choices is less than two, n is the optimal choice for a depositor, otherwise it is w.

The experiment is organized in three phases (Phase 1, Phase 2 and Phase 3).[7] Feedback information is provided after each phase and actual earnings are determined at the end of the experiment.

In Phase 1, the financial literacy and the general knowledge of participants are elicited via a multiple choice questionnaire (13 questions in total).[8] The time limit to answer each question is set to 90 seconds. Wrong answers are penalized and unanswered questions are neither rewarded nor penalized. The total score is converted into the probability of winning the high prize (150 Zed) instead of the low one (50 Zed) in a binary lottery.[9] Feedback information include the result for the two groups of questions and the winning probability.

In Phase 2, participants play the bank-run game in groups of fixed size (5, 7 or 10 subjects); i.e., in small, medium and large banks, respectively. The bank-run game is repeated for 20 rounds in small and medium banks and in large banks for 25 rounds. We also elicit non-incentivized expectations about current-period withdrawal choices of their fellow depositors as a preparatory task to the actual bank-run game. End-of-round feedback includes the own payoff and the number of withdrawals in the own bank. One round is randomly selected for payment. Participants interact anonymously and are re-matched in each round.[10]

In Phase 3, we elicit participants' risk aversion using the Holt and Laury (2002) protocol. Prizes for the safe lottery are 200 Zed and 160 Zed, while prizes for risky lottery are 385 Zed and 10 Zed, so that the magnitudes are comparable with the payoffs in the bank-run game.

either (steady state) equilibrium

[7] The Instructions are provided in Appendix B.

[8] The questionnaire consists of seven questions on financial literacy. Three on the topics of inflation, shares and interest compounding and are adapted from the Basic and Advanced Literacy Questions in Rooij et al. (2011). One question on pricing of an asset is adapted from PISA 2012 Financial Literacy Questions and Answers, proposed by OECD (2012a). Two questions relate to portfolio decisions and to the inter-temporal budget constraint and are proposed in an original formulation. The seven general knowledge questions are adapted from the PISA released items on mathematics, problem solving and field trial cognitive abilities (see OECD, 2012c, OECD, 2012b and OECD, 2015). In the experiment, no explicit reference is made to either *financial literacy* or *general knowledge*.

[9] The winning probability ranges from 5% to 95% as the score increases from −6.5 to 13 points. The denomination of the currency is borrowed from OECD (2014).

[10] The implementation of the re-matching does not exclude that two or more subjects are assigned to the same bank in different rounds.

The actual payment for the experiment is determined after Phase 3 and it is equal to the sum of (*i*) the prize of the binary lottery associated to Phase 1, (*ii*) the payoff of the randomly selected round of Phase 2 and (*iii*) the prize of the binary lottery from the risk aversion elicitation task. The Phase 1 and Phase 3 lotteries are played by the computer. The payment round for Phase 2 and the lottery pair for Phase 3 are randomly selected using a public device (bingo numbers). Treatments are related to information revelation, since we want to study the effect of revealing, within a bank, information on the score of the fellow depositors in the financial literacy or general knowledge questionnaires.

Table 2: Sessions' overview

Session	Treatments	Bank size (# depositors)	Number of participants	Rounds	Number of banks per round
1	NO	5	25	20	5
2	NO	7	21	20	3
3	NO	10	20	25	2
4	FI	5	25	20	5
5	FI	7	21	20	3
6	FI	10	20	25	2
7	GI	5	25	20	5
8	GI	7	21	20	3
9	GI	10	20	25	2

In the baseline treatment, NO, no information on the result of the questionnaire is revealed. In the Financial Information treatment, FI, (General Information treatment, GI) the minimum, the maximum and the average score in the financial literacy (general knowledge) questions are privately communicated to depositors within each bank. Each information treatment is replicated for every group size.

The experiment, programmed with zTree Fischbacher (2007) was conducted in the CESARE lab at Luiss Guido Carli (Rome, Italy) between November 2015 and March 2016. 198 subjects, recruited with the Orsee (Greiner, 2015), participated in the overall nine sessions (see the overview in Table 2).[11] The average payment was 23 euro.

5 Hypotheses

In this section we present our conjectures about our main research questions. Concerning the role of the group size, since we control for the tightness of the coordination game as in Arifovic et al. (2013) we do not expect the size of the bank to affect the strategic interaction among depositors:

Hypothesis Group Size (GS). *Given that we assume the same coordination tightness across banks, we do not expect the group size to significantly affect subjects' choices.*

In the experiment, subjects repeatedly face the same task and receive information about fellow depositors' decisions via end-of-round feedback. Consistently with the evolutionary approach

[11] 47.73% of participants were female, 65.91% from Economics, 21.59% from Law and 11.74% from Political Science.

described in the theoretical benchmark, we assume that participants follow an adaptive behavior and take current decisions on the basis of previous-round outcomes. Hence, we state a second hypothesis:

Hypothesis Adaptive Behavior (AB). *We expect that subjects significantly base their decision in the current round on the previous-round outcome.*

Hypothesis AB implies that subjects (mostly) select, in the current round, the best response to fellow depositors' choices in the previous round. However, given the similarities of our design and that of Arifovic et al. (2013), we expect that our subjects display a certain degree of experimentation as theirs did. Therefore, we formulate the following:

Hypothesis Experimentation (EX). *Despite the adaptive behavior mentioned in Hypothesis AB, we expect a non negligible fraction of subjects to experiment with choices that differ from previous-round best response.*

6 Econometric Strategy

When modeling current withdrawal decisions, we consider two main drivers: one based on state dependence and one based on strategic deliberation. Regarding the first one, current decisions may be affected by own past withdrawal decision (pure state dependence) and by unobserved individual factors (spurious state dependence). If unobserved heterogeneity is correlated over time, own past decisions may appear a determinant of current decisions solely because they are a proxy for such temporally persistent unobservables (Heckman, 1981). Regarding strategic deliberation, current decisions should be consistent with expectations about opponents' behaviors. To disentangle the effects of pure and spurious state dependence, as well as strategic deliberation, we use the following dynamic correlated random-effects probit model:

$$\begin{aligned} Pr(y_{it} = 1 | x_{it}, \boldsymbol{z}_i, y_{it-1}, c_i) &= \Phi(\gamma y_{it-1} + x_{it}\beta + \boldsymbol{z}_i\boldsymbol{\theta} + c_i + \tau_p) \quad (3) \\ c_i | x_{it}, y_{i0} &\sim \mathcal{N}(\alpha + \nu \bar{x}_i + \eta y_{i0}, \sigma_u^2), \quad (4) \end{aligned}$$

where equation (4) follows from $c_i = \alpha + \nu \bar{x}_i + \eta y_{i0} + u_i$, with $u_i \sim \mathcal{N}(0, \sigma_u^2)$ and independent of y_{i0} and $\bar{x}_i$. The dependent variable of the model is the conditional probability that individual i withdraws at time t, i.e., $Pr(y_{it} = 1)$, given x_{it}, $\boldsymbol{z_i}$, y_{it-1} and c_i. In this specification, c_i controls for time-invariant unobserved heterogeneity that may be correlated with x_{it} and y_{i0}. The time-varying covariates are the share of expected withdrawals from fellow depositors (x_{it}) and the individual withdrawal decision in previous round (y_{it-1}). We control for time effects by clustering rounds in groups of 5 using τ_p with $p = 1, \ldots, 5$.[12] As for the time-invariant covariates ($\boldsymbol{z}_i$), the model includes dummies for bank size (`N7` and `N10`), dummies for whether the depositors received (payoff-irrelevant) information about the fellow depositors' financial literacy (`FI`) or general knowledge (`GI`) and, finally, a set of demographic controls (see Table 4). The latter includes, among others, the number of

[12] In banks with 5 and 7 depositors, $p = 1, \ldots, 4$, as the sessions consist of 20 rounds.

safe choices selected in Phase 3 as a proxy for risk aversion (`safeCh`) and the individual scores on financial literacy and general knowledge questions(`scoreFin` and `scoreGen`). As pointed out by Wooldridge (2005), once the initial conditions are controlled for, the parameters of this model can be consistently estimated by conditional maximum simulated likelihood.[13]

Regarding *strategic experimentation*, we define it as an observed behavior of subject i in round t that differs from the best response in the $(t-1)$-round played by i's group. Each subject would be able to compute such $(t-1)$-best response, using the feedback received at the end of round $(t-1)$ and the payoff matrix of the bank-run game.[14] Naturally, a participant experiments with no withdrawing at t if withdrawing is the $(t-1)$-best response; while (s)he experiments with withdrawing if no withdrawing is the $(t-1)$-best response. Since in our analysis it will be relevant to distinguish these two instances of experimentation, we introduce the following notation: if subject i in round t experiments with withdrawing, we let $e_{it}(w) = 1$; if (s)he experiments with no withdrawing, we let $e_{it}(n) = 1$; finally, if (s)he does not experiment either with withdrawing or with no withdrawing, we let $e_{it}(n) = e_{it}(w) = 0$. The next table summarizes the instances of strategic experimentation:

Table 3: Strategic experimentations, $e_{it}(n)$ and $e_{it}(w)$.

		$(t-1)$-*best response*	
		w^*_{it-1}	n^*_{it-1}
decision of subject i at t	w_{it}	$e_{it}(n) = 0$	$e_{it}(w) = 1$
	n_{it}	$e_{it}(n) = 1$	$e_{it}(w) = 0$

Taking into account the two types of strategic experimentation, which depend on what would be the best response to previous-round choices, our setup defines two unbalanced panel samples with gaps, which does not allow the estimation of a dynamic model for the probability of experimentation. Therefore, we will use the following correlated random-effects probit model:

$$Pr(y_{it} = 1 | \boldsymbol{x}_{it}, \boldsymbol{z}_i, c_i) = \Phi(\boldsymbol{x}_{it}\beta + \boldsymbol{z}_i\boldsymbol{\gamma} + c_i + \tau_p) \tag{5}$$

$$c_i | \boldsymbol{x}_{it} \sim \mathcal{N}(\alpha + \nu\bar{\boldsymbol{x}}_i, \sigma_u^2), \tag{6}$$

where $y_{it} \in \{e_{it}(n),\ e_{it}(w)\}$ is the experimentation of depositor i in round t, $\boldsymbol{z}_i$ and τ_p are same covariates defined in model (3)–(4), and c_i is given the same interpretation as of (3)–(4). In this new random-effect probit, we include in $\boldsymbol{x}_{it}$ a control capturing the distance between the share of withdrawals observed by subject i in $(t-1)$ and the threshold $\tilde{\mu}_w$ ($\texttt{Distance}_{t-1}$),[15] and a dummy that compares expectations and $(t-1)$-feedback. Specifically, when estimating the probability of experimenting with withdrawing, the dummy is equal to 1 if the share of expected withdrawals is greater than the previous-round share of withdrawals (δ^+); similarly, when estimating the probability of experimenting with no withdrawing, the dummy is equal to 1 if the share of expected withdrawals

[13] Estimation of model (3)–(4) has been performed using the Stata command `xtprobit, re`.

[14] Indeed, for each constellation of fellow depositors' there is a single payoff maximizing decision: if there are less than $\tilde{\mu}_w$ withdrawals, the best response is to not withdraw, otherwise it is to withdraw.

[15] For comparability of the data across the different size treatments, the expected number of withdrawals has always been scaled by the total number of depositors in the bank.

is less than the previous-round share of withdrawals (δ^-). These dummies highlight whether or not expectations are aligned with previous feedback, which may reveal that, for those subjects, the convergence process toward the (t-1)-best response can be reversed.

Table 4 summarizes the variables used in our analysis. In terms of the demographics, the sample of participants is fairly balanced in terms of gender and the average subject is less than 22 years old, risk averse and performs fairly well both in the financial literacy and the general knowledge questionnaire.

Table 4: List of variables

Variable	Mean	sd	Description
Withdraw	0.792	0.406	Dummy: subject has decided to withdraw in current round
Expectation	0.708	0.295	Expected share of opponents who will decide to withdraw
Feedback_{t-1}	0.784	0.232	Share of opponents who withdrew in period $t-1$
N5	0.352	0.478	Dummy: 5-depositor bank treatment
N7	0.296	0.456	Dummy: 7-depositor bank treatment
N10	0.352	0.478	Dummy: 10-depositor bank treatment
NO	0.333	0.471	Dummy: No Information treatment
FI	0.333	0.471	Dummy: Financial Information treatment
GI	0.333	0.471	Dummy: General Information treatment
Distance_{t-1}	0.392	0.229	Distance between the number of opponents' withdrawals observed in the previous round and the number of withdrawals that causes a switch in the best response (both in share)
δ^-	0.382	0.486	Dummy: expected withdrawals in $t <$ observed withdrawals in $t-1$
δ^+	0.250	0.433	Dummy: expected withdrawals in $t >$ observed withdrawals in $t-1$
Demographics			
Female	0.417	0.493	Dummy: subject is a female
safeCh	6.333	1.719	Number of safe choices made in the risk elicitation task
Age	21.92	2.070	Age
eduMother	0.486	0.500	Dummy: subject's mother has academic-level education
scoreFin	2.896	1.801	Score of the subject on questions with financial content
scoreGen	2.805	2.030	Score of the subject on questions with general content

7 Results

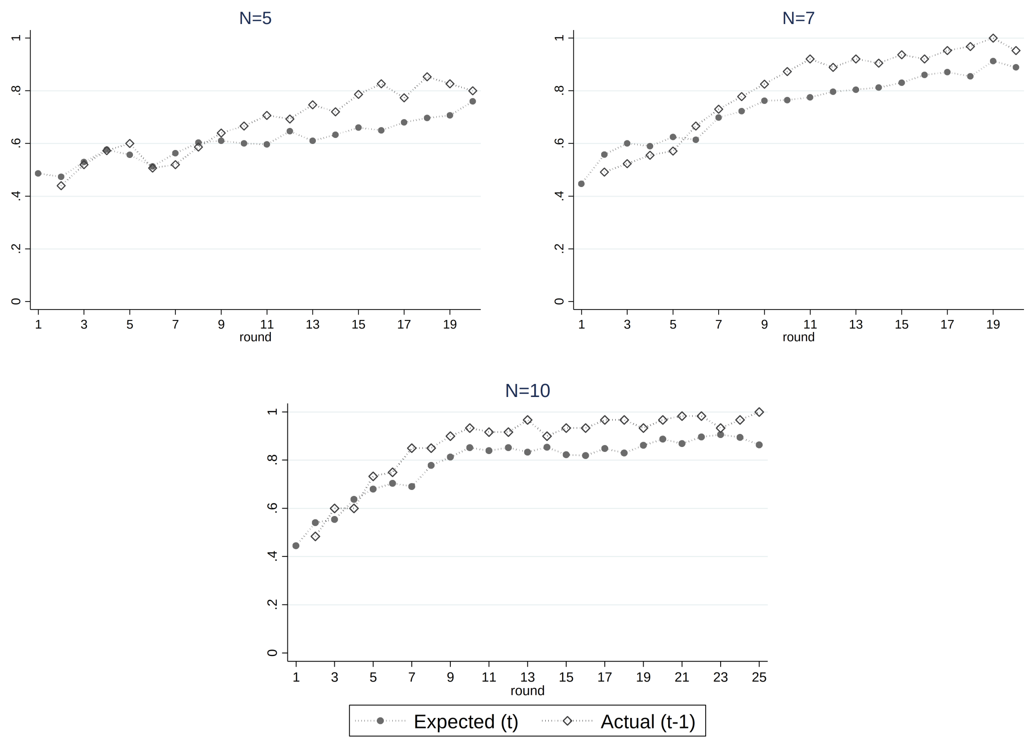
In this section, we present the analysis of the determinants of participants' decisions. At first we focus on withdrawal decisions and then on strategic experimentation.

7.1 Adaptive Behavior

When analyzing the determinants of withdrawal decisions, we consider two main drivers: past withdrawals, which are observed via end-of-period feedback information, and expected withdrawals, which are self-reported in each round before deciding whether to withdraw or not.

Figure 1 shows the shares of actual and expected withdrawals across rounds, distinguishing banks by size. In first round(s), these rates are quite high and rather similar across banks of different size. Subsequently, they increase faster in larger banks, which in final rounds exhibit universal withdrawing. Although participants are aware that depositors are reshuffled between banks in each round, the rates of expected and (previous-round) actual withdraw exhibit strikingly similar

Figure 1: Expected (at round t) and actual (at round $t-1$) withdrawal rates.



dynamics. This suggests that, irrespective of banks' sizes, beliefs about current fellow depositors' behavior are correlated with past observed decisions.

Recall that, in our design, expectation elicitation is a preparatory task for bank-run game, which is not incentivized. Figure 2 shows that participants' choices are fairly consistent with their expectations, especially when the expected rate of withdrawals is above $\tilde{\mu}_w$. In the figure, the solid line denotes the best-response withdrawal rates, given the number of expected withdrawals,[16] and the diamond-dotted line the actual ones. Finally, the bars provide the distribution of subjects' (point) expectations.[17] Overall the majority of participants chooses the best response given the expectations. Nevertheless, there is a non-negligible share of subjects who does not exhibit decisions consistent with expectations.

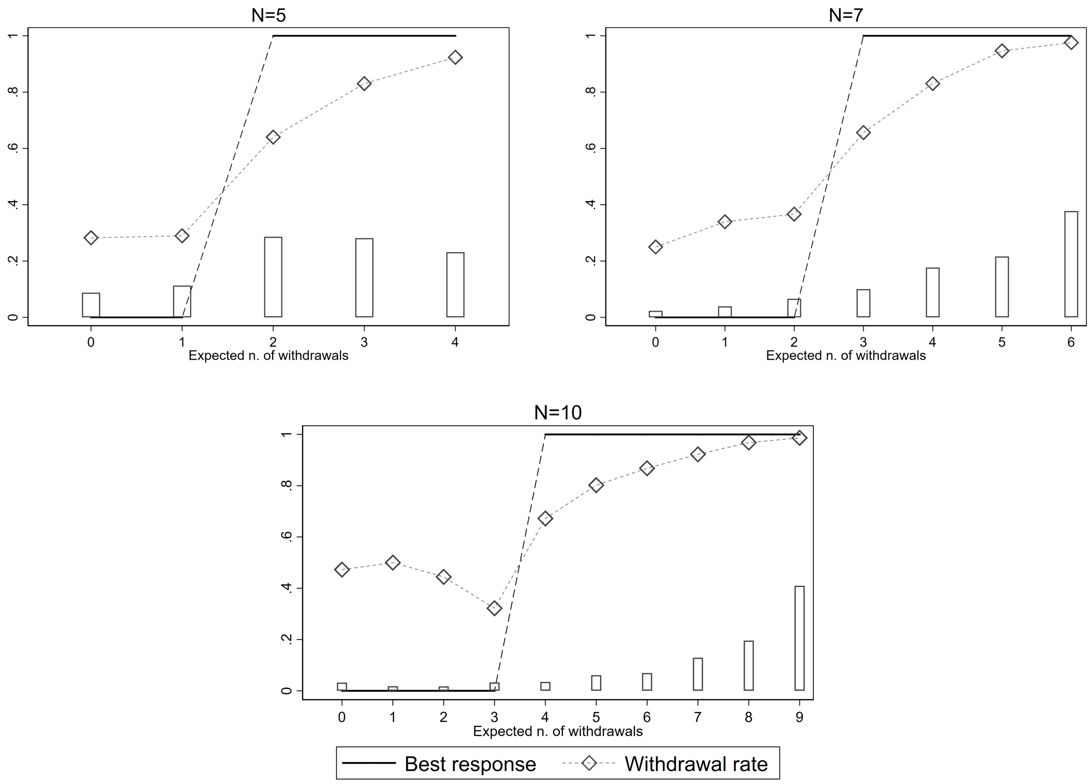
We now turn to the results of the econometric analysis. Table 5 reports average marginal effects (AMEs) for the two specifications of the dynamic correlated random-effects probit (3)–(4), one with expected withdrawals (model $Expectation_t$) and the other with actual withdrawals in the previous round (model $Feedback_{t-1}$). For sake of consistency, both specifications include the own decision in the previous round.

The fraction of total variance contributed by the random-effects (ρ) is estimated to be around 30% (see the bottom panel in Table 5). When ρ is zero, the random-effects are unimportant and the panel estimator is not different from the pooled one. This hypothesis ($H_0 : \rho = 0$) is strongly rejected

[16]Since the best response in our game is always unique, for each given profile of opponents' decisions, the solid line is equal to zero if the expectation rate is below the threshold $\tilde{\mu}_w$ and equal to 1 otherwise.

[17]Specifically, the bars measure the share of subjects who expect k fellow depositors to withdraw in the current round, with $k = 0, ..., N-1$.

Figure 2: Best response and actual withdrawal rates.



by the likelihood-ratio test which compares the pooled and the random-effects probit. We interpret this result as evidence of significant spurious state dependence captured by the random-effects.

Regarding the AMEs of the various regressors, specification $Expectations_t$ reveals that the main driver of the withdrawal decision in each round are the expected withdrawals; in particular, we estimate that an increase of 10% in the (share of) expected withdrawals corresponds to an average increase of the withdraw probability of 4%. Interestingly, the AME for the withdrawal decision in previous round is not statistically significant suggesting that, once time invariant unobserved effects and expectations are controlled for, there is no evidence of pure state dependence in the withdrawal decision.[18] On the other hand, we find that the first-period withdrawal decision matters: compared to those that chose not to withdraw, subjects who chose to withdraw in the first round have, on average, a 9% higher withdrawal probability in the subsequent rounds. Being in a large bank (10 depositors) increases by about 5% the likelihood of withdrawal relative to being in a small bank. We also find that in the specific settings of our experiment, revealing information about fellow depositors' financial literacy (FI) or general knowledge (GI) does not play a role for the individual withdrawal decision. As aforementioned, in order to explicitly control for some observable heterogeneity, we also included in the specification a set of demographic controls, but none of them

[18] We strongly reject the null hypothesis of joint statistical significance of the lagged withdrawal decision and initial conditions parameters ($H_0 : \gamma = \eta = 0$, see the last row of Table 5). Hence, even though there is no evidence of pure state dependence, it is worth having a dynamic specification.

Table 5: Determinants of withdrawal decision

	$Expectation_t$	$Feedback_{t-1}$
Expectation	0.390***	
	(0.019)	
Feedback_{t-1}		0.173***
		(0.028)
Withdraw_{t-1} =1	0.019	0.053***
	(0.012)	(0.014)
Withdraw_0 =1	0.090***	0.112***
	(0.018)	(0.022)
N7=1	0.030	0.064
	(0.022)	(0.035)
N10=1	0.056*	0.090*
	(0.023)	(0.044)
FI=1	0.005	-0.002
	(0.023)	(0.029)
GI=1	0.001	-0.008
	(0.022)	(0.028)
Demographics	✓	✓
Grouped round dummies	✓	✓
Observations	4062	4062
AIC	2433.96	2935.39
ρ	0.31	0.34
$H_0 : \rho = 0$	0.000	0.000
$H_0 : \gamma = \eta = 0$	0.000	0.000

Standard errors in parentheses
*p<.05; **p<.01; ***p<.001

is statistically significant. Hence, neither the risk attitude nor the individual scores on financial or general knowledge affect subjects' decisions.

Specification $Feedback_{t-1}$ offers similar insights, in that the end-of-round feedback information together with own previous-round decision constitute major determinants of subjects' (current-period) choices.

Overall the above observations allow to confirm Hypothesis AB:

Result 1. *Subjects' withdrawal choice is determined by previous-period interactions, either directly through the observed choices of fellow depositors in* $(t-1)$ *or indirectly by the effect on expectations about the fellow depositors' withdrawals in* t*.*

Concerning Hypothesis GS, contrary to our conjecture we have found that:

Result 2. *Group size is a significant determinant of the withdrawal decision. In particular, the probability to withdraw is higher in large groups.*

As a complement to the previous pooled analysis, to highlight the role of bank size on the magnitude and significance of the AMEs, in Table 6 we estimate our model separately for each

Table 6: Determinants of withdrawal decision

	$N = 5$	$N = 7$	$N = 10$
Expectation	0.504***	0.402***	0.260***
	(0.038)	(0.033)	(0.023)
Withdraw_{t-1} =1	0.001	0.015	0.037
	(0.021)	(0.021)	(0.020)
Withdraw_0 =1	0.188***	0.088***	0.028
	(0.044)	(0.026)	(0.015)
FI=1	0.093	-0.010	-0.055**
	(0.052)	(0.034)	(0.020)
GI=1	0.093	0.017	-0.040*
	(0.050)	(0.031)	(0.020)
Demographics	✓	✓	✓
Grouped round dummies	✓	✓	✓
Observations	1425	1197	1440
Log-lik	-563.07	-301.08	-292.49
ρ	0.37	0.22	0.01
$H_0 : \rho = 0$	0.000	0.000	0.889
$H_0 : \gamma = \eta = 0$	0.000	0.001	0.005

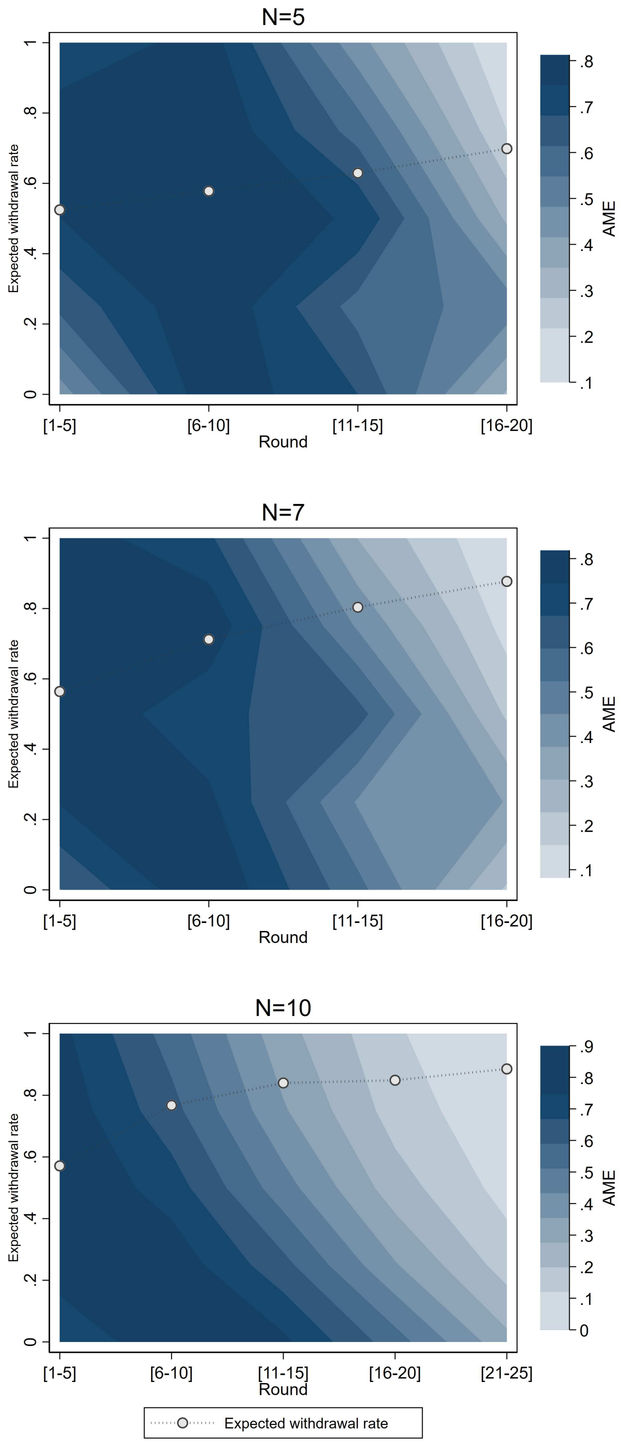
Standard errors in parentheses
*p<.05; **p<.01; ***p<.001

group size. In doing this we focus on specification $Expectation_t$. Indeed, while both specifications in Table 5 identify an adaptive behavior of the participants, there is evidence that the effect of expectations absorbs the pure state dependence that we found in specification $Feedback_{t-1}$, i.e. the effect of own withdrawal decision at $t - 1$. Our interpretation is that expectations capture a process which includes not only the end-of-round feedback information but also past own decisions and personal unobserved characteristics. Furthermore, $Expectation_t$ also exhibits a better fit (see Akaike information criterion, AIC, reported in Table 5).

According to Table 6, the initial-condition effect vanishes for large banks, to the point that the best model for 10-depositor banks is the pooled probit (as shown by the diagnostics reported in Table 6). Moreover, in these banks the coefficient of expectations halves compared to small ones. This is consistent with the fact that, in large banks, both expectations and withdrawals quickly reach a very high level, which persists until the end of the experiment (see Figure 1). As for the dummies capturing the information treatment, in large banks they are (weakly) significant and reduce the probability of withdrawing. However, we acknowledge that this effect may be confounded with session effects which the current design does not allow to disentangle.

Given the important role of expectations in the probability of withdrawing, we want to analyze how their AMEs evolve across rounds for each bank size (see Figure 3). The axes of the Figure 3 report, respectively, the rounds in blocks of five and the average expectation of depositors. The white dots represent the average expectations for given block of rounds. For all sizes we can see that they are increasing over rounds with a steeper dynamics in large banks. Furthermore, the shaded area represents the average marginal effect of any given level of expectations on the withdrawal

Figure 3: Average Marginal Effect of `Expectations` across rounds



probability over groups of rounds.

These figures allow for a twofold interpretation: on the one hand, by fixing the level of expectations one can analyze how their marginal effect evolves over rounds; on the other hand, keeping the round constant one can evaluate how the marginal effects change as the level of expectations varies. Consider for example the case $N = 10$ and fix the expected number of withdrawals at the level observed in rounds 1 to 5, i.e. the first white dot. As the game proceeds (x-axis), the marginal effect of a unit increase in the share of expected withdraw on the probability of withdrawing decreases, i.e. the shade becomes lighter as we move to the right. The figures allow to visualize the effect of expectations as well: for any given group of rounds, the marginal increase in the probability of withdraw decreases as the expected number of withdrawals grows, i.e. the shade becomes lighter as we move upward.

The effect is quite heterogeneous across bank sizes, even though it is a common feature that the AME decays as the repetitions of the game increase. When $N = 5$ the effect is stronger and more persistent, i.e. the darker share lasts until the third block of round; for $N = 7$ there still is a strong effect up to round 10. Lastly, when $N = 10$ we observe a clear time-expectation trade off: the effect is strong only for low levels of expected withdrawals, which however are observed only by few individuals and in very early rounds (see dashed line in the last sub-graph).

We conclude by comparing the gathered evidence with those of the closely related experiments of Arifovic et al. (2013) and Garratt and Keister (2009) for 10-depositor and 5-depositor banks, respectively. In all sessions, we observe a predominance of withdrawal decisions, which already in the first rounds account for at least 40% of all choices and increase with repetitions, therefore, contrary to the findings of Arifovic et al. (2013), we do not get indeterminate predictions in terms of equilibrium analysis, rather a strong indication that subjects tend to coordinate on the bank-run inefficient equilibrium. Our results can be due to differences in the protocol: Arifovic et al. (2013) relies on a partner matching protocol while we implement a stranger matching one. The lack of a common history of play and the re-matching process leading to face new opponents at every round, with a more uncertain belief-formation process, can reduce the possibility to sustain efficient coordination and may increase the withdrawal probability when compared to experiments that implement a partner-matching protocol (see, e.g. Devetag and Ortmann, 2007). For small banks (5-depositors), the withdrawal rates we find contrast with those of Garratt and Keister (2009), who also adopt a stranger matching protocol. In their case, however the coordination tightness of the strategic interaction is less stringent[19] and this may explain the difference since it is known that in bank-run games the results depend on the coordination requirement imposed on the subjects (see, e.g., Arifovic et al., 2013).

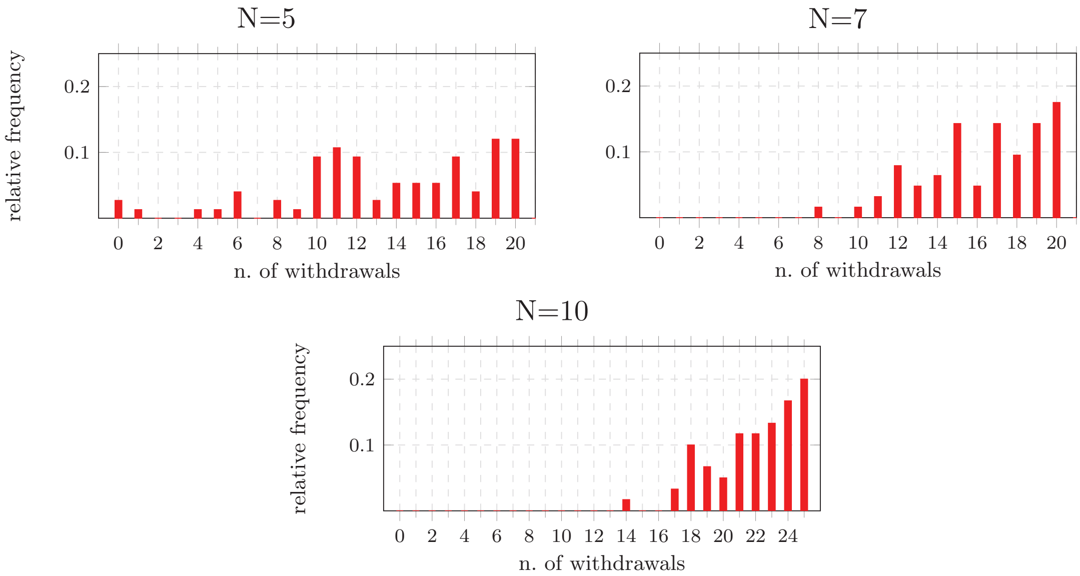
Table 7: Shares of subjects who never switch and who switch more than twice.

	N=5	N=7	N=10
Share of subjects who never switch	0.147	0.175	0.2
Share of subjects who switch more than twice	0.64	0.527	0.5

Concerning the role of the bank size, descriptives about subjects behavior suggest that perceived strategic uncertainty changes with the size of the bank. In Table 7 we report the share of subjects who never switch and the one of subjects who switch more than twice. A subject switches when choosing different actions in two successive rounds. According to the table, the share of subjects

[19] In their experiment, withdraw is the best response when at least four depositors decide to withdraw, while in ours this occurs with at least two withdrawals.

Figure 4: Distribution of individual withdrawals



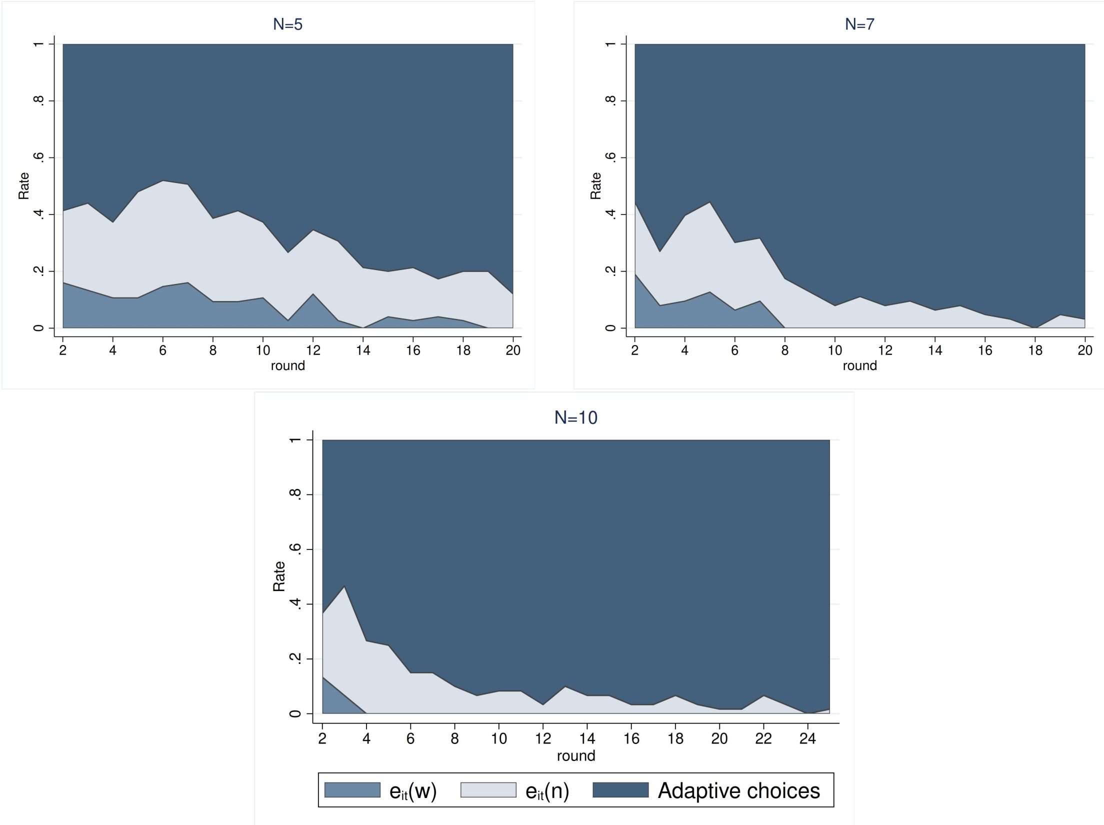
who never switches is increasing with the size while the opposite holds for the share of subjects who switches more than twice. This supports the view that perceived strategic uncertainty is higher in smaller group. Furthermore, Figure 4 shows that subjects tend to withdraw more in larger groups, since the distribution of withdrawals shifts to the right, with a sizeable share of subjects withdrawing in all periods in 10-depositor banks. Combining information in Table 7 and Figure 4, we observe that, while in small banks some of the subjects who never switch choose not to withdraw, in large banks all subjects who never switch decide to withdraw. All these observations confirm that in smaller banks the perceived strategic uncertainty is higher. Overall, for all sizes we observe a clear convergence process toward the inefficient equilibrium, the perceived strategic uncertainty can explain the lower convergence rate and probability to withdraw that we observe in small banks.

7.2 Strategic Experimentation

In this section we analyse the extent and the determinants of the strategic experimentation. Figure 5 shows the relative size and the dynamics of the aggregate decisions by bank size. The medium-shade area represents the frequency of experimentation with withdrawing, $e_{it}(w)$, while the lightest area represents the frequency of experimentation with no withdrawing, $e_{it}(n)$. Finally, the darkest area represents the frequency of subjects choosing in t the action that was optimal given the behavior of their group in $(t-1)$, i.e. the $(t-1)$-best response, a behavior that is predominant for all group sizes.

Overall, strategic experimentation is not negligible: in initial rounds it counts up to about half of the participants' behavior when the groups are small; it is more frequent in earlier rounds and in smaller banks. However, it quickly decays across rounds. In large banks, in which subjects sooner adopt a generalized withdrawal behavior, the frequency of experimentation fades away more rapidly than in small and medium banks. Since in our experiment the withdrawal shares are relatively high already in the first round and rapidly increase with rounds (see Figure 1), it seldom happens

Figure 5: Rate of experimentation and of adaptive choices



that no withdrawing is the $(t-1)$-best response. For this reason $e_{it}(w)$-experimentation is rarely observed and concentrates in initial rounds. Therefore, we mostly observe experimentation in initial rounds and of $e_{it}(n)$-type; in fact as withdrawal rates increase over rounds, when it is clear that withdrawing is the predominant choice, subjects stop experimenting. Given this evidence we confirm Hypothesis EX:

Result 3. *Strategic experimentation with no withdrawing is sizeable especially in earlier rounds and in small groups. However, its occurrence quickly decays across rounds. Experimentation with withdrawing shares similar features, but is rarely observed.*

Regarding the determinants of strategic experimentation, Table 8 shows the estimates of the random-effect probit model (5)–(6). Since the sample size for $e_{it}(w)$ is admittedly small, we report the results for completeness but, henceforth, focus our comments on $e_{it}(n)$. Significant determinants of the experimentation probability are: $\texttt{Distance}_{t-1}$, δ^- and the size dummies (both `N7` and `N10`).

Experimentation is more likely in small banks than in medium and large ones, the probability to experiment in 10-depositor and 7-depositor banks when compared with 5-depositor banks decrease by around 7% and 6%, respectively.

The effects of $\texttt{Distance}_{t-1}$ and δ^- on the probability of experimentation reveal an interesting strategic component in the participants' decision process, which is a new aspect in this literature.[20]

[20] In Arifovic et al. (2013), only a subset of the participants could identify the best response in the bank-run game of the previous period. Given our design, all depositors can identify the best response at $t-1$ thanks to the feedback they receive, which leads us to fully deduce the strategic aspect of their experimentation behavior.

Table 8: Determinants of experimentation probability

	$e_{it}(n)$	$e_{it}(w)$
Distance$_{t-1}$	-0.310***	0.536
	(0.035)	(0.297)
δ^-	0.173***	
	(0.012)	
δ^+		0.431***
		(0.047)
N7=1	-0.064*	-0.018
	(0.027)	(0.084)
N10=1	-0.077*	0.083
	(0.038)	(0.136)
FI=1	-0.008	0.130
	(0.026)	(0.078)
GI=1	-0.023	0.075
	(0.025)	(0.072)
Demographics	✓	✓
Grouped round dummies	✓	✓
Observations	3774	288
Log-lik	-1168.09	-133.09
ρ	0.35	0.54
$H_0 : \rho = 0$	0.000	0.000

Standard errors in parentheses
*p<.05; **p<.01; ***p<.001

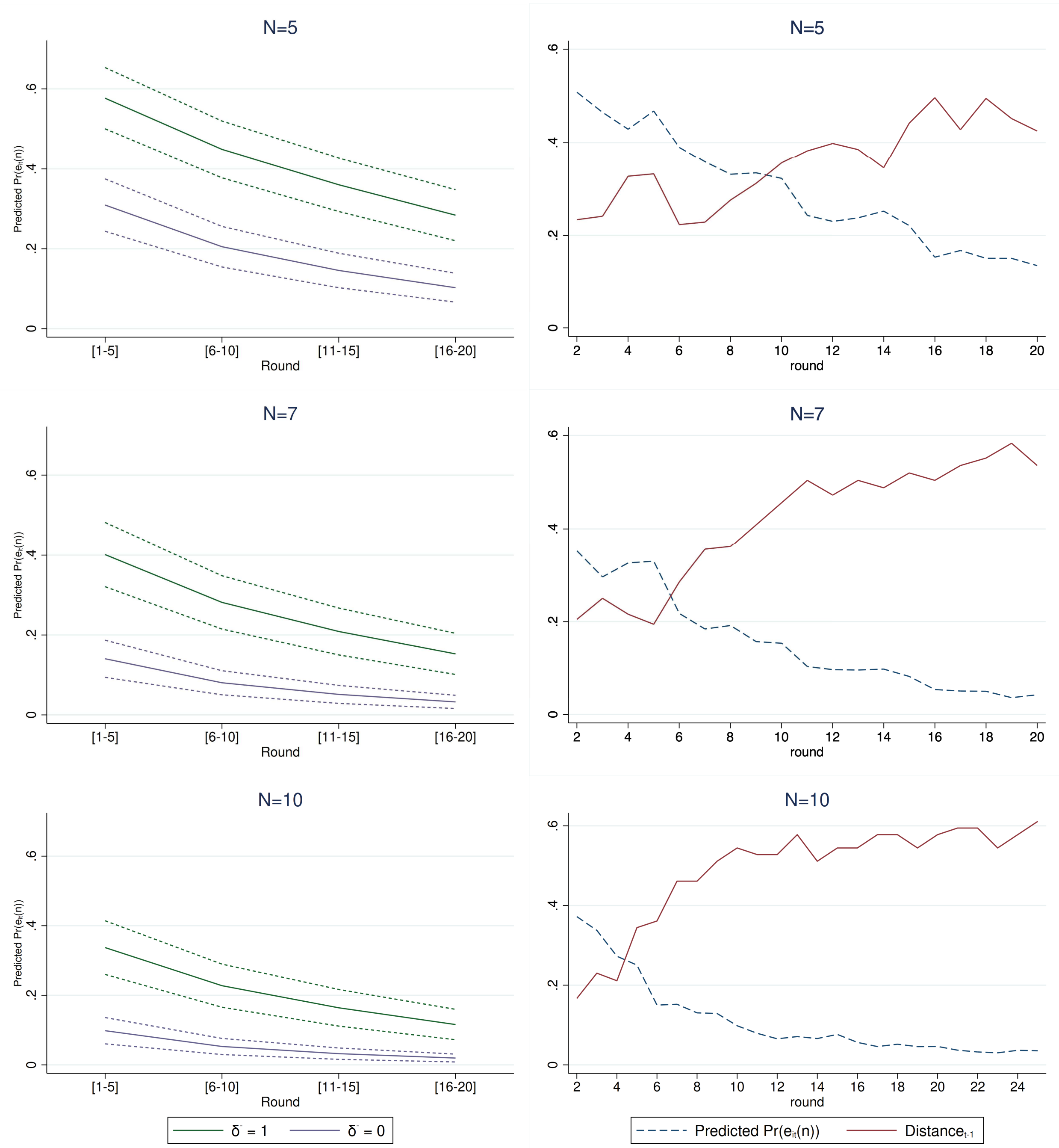
Indeed, we observe that participants reduce the likelihood of experimentation when the withdrawals in the previous round are more distant from the threshold $\tilde{\mu}_w$. We interpret this result as evidence of individual attempts to promote convergence toward the payoff-dominant equilibrium: when the observed share of withdrawals is close to the threshold $\tilde{\mu}_w$ that induces a shift in the participants' best response, subjects may expect that these attempts may be more likely to succeed. In addition, since the individual payoff from not withdrawing is decreasing in the share of opponents' withdrawals, the cost of experimenting is increasing in $\texttt{Distance}_{t-1}$, which is also coherent with a negative impact of this variable on the probability of experimentation.

Furthermore, when participants expect less withdrawals than those in the previous round (δ^-=1), the probability of experimentation increases. In this case, subjects' expectation may suggest that they are more optimistic about a possible convergence to the payoff-dominant equilibrium.

Regarding the bank size, our findings suggest that, in small banks, depositors believe that their choices can be more effective in leading the group toward the no-run equilibrium due to the small group size and higher turnover of fellow depositors; therefore, they are more likely to experiment. Moreover, all results gathered about strategic experimentation are coherent with descriptives presented in Table 7 and Figure 4 and our interpretations relating them to perceived strategic uncertainty. In particular, subjects experiment more in small groups in which perceived strategic uncertainty is higher, which highlights a weaker convergence process toward the inefficient equilibrium.

Given our results, as it was for the withdrawal probability, our Hypothesis GS is not confirmed:

Figure 6: Predicted experimentation probability by (group of) round by δ^- (left column) and overall with lineplot of $\texttt{Distance}_{t-1}$ (right column)



Result 4. *The size of the group is significant determinant of the experimentation decision. In particular, the probability of experimentation is lower in larger groups.*

In Figure 6, we further highlight the linkages between strategic experimentation, $\texttt{Distance}_{t-1}$ and δ^- for each group size. All graphs plot the predicted probability of experimentation by (group of) round. However, in the left column we distinguish for values of δ^- and show that the probability of experimenting, although monotonically decreasing with repetitions, is significantly higher when participants expect withdrawals to be lower than the previous round ($\delta^- = 1$) compared to when they expect them to be at least the same ($\delta^- = 0$). This effect of observed and expected withdrawals is stronger in smaller banks. Instead, in large banks we observe a much lower probability of experimentation when participants expect a higher number of withdrawals.

The right panels report the dynamics of $\texttt{Distance}_{t-1}$ (continuous, red line) across all rounds of the game and the experimentation probability (dotted, green line) predicted by our model. All three figures clearly show that $\texttt{Distance}_{t-1}$ increases with the repetition of the game, and it does so at a faster rate in medium and large banks. As $\texttt{Distance}_{t-1}$ increases, the (predicted) experimentation probability fades out, again at a faster rate in medium and large banks. Overall, these results enlarge our findings and support our strategic interpretation of the experimentation phenomenon.

8 Conclusion

We examine a bank-run game with groups of different size, taking a comparative approach. For comparability across groups, following Arifovic et al. (2013) we parameterize the game by a common coordination parameter. In all sessions, we observe a predominance of withdrawal decisions, which already in the first rounds account for at least 40% of all choices and increase with repetitions, with a strong indication that subjects tend to coordinate on the bank-run inefficient equilibrium.

We examine two possible main drivers for individual withdrawal decisions: first, the observed previous-round withdrawal choices taken in her group; second, subjects' expectations about fellow depositors' withdrawal choices to be made in the current period. Expectations seem to explain withdrawal behavior better than feedback, although both specifications are consistent with an adaptive behavior of the participants of our experiment. Eventually, the probability of withdrawal of subject i in round t is determined by previous-period (strategic) interactions. This mechanism is more evident in small and medium banks. In large banks, instead, the relevance of expectations about fellow depositors' choices is much smaller and it rapidly declines with rounds.

To complement our understanding on subjects' adaptive behavior, we investigate whether participants also attempt at some form of strategic experimentation. We find evidence that subjects experiment with no withdrawing, i.e. they choose not to withdraw in t when withdrawing is the $(t-1)$-best response. This behavior is strategic because subjects take into account the expected costs and gains that they can attain with this decision. On one hand, subjects experiment more if the $(t-1)$-observed withdrawals are closer to the threshold that induces a shift in the optimal response. On the other hand, subjects are more likely to experiment when they expect to face a lower number of withdrawals relative to what observed in $(t-1)$. The latter identifies a new determinant of experimentation probability relative to existing findings. Our evidence is consistent with subjects expecting that their attempt at choosing no-withdrawal may successfully induce convergence toward the no-run (efficient) equilibrium. At the same time, in case of failure the cost of experimenting would have been lower, since the payoff by choosing no withdrawing is decreasing in the share of depositors who withdraws. Hence they experiment with no withdrawing when expecting higher current and future payoffs from such a action.

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Appendix A Additional Materials

Table 9: Payoff Matrix for 7-depositor Banks

	Payoff if you withdraw ○	Payoff if you do not withdraw ●
○○○○○○	98	7
●○○○○○	117	57
●●○○○○	122	96
●●●○○○	122	115
●●●●○○	122	127
●●●●●○	122	134
●●●●●●	122	150

Table 10: Payoff Matrix for 10-depositor Banks

	Payoff if you withdraw ○	Payoff if you do not withdraw ●
○○○○○○○○○	99	0
●○○○○○○○○	117	7
●●○○○○○○○	122	63
●●●○○○○○○	122	90
●●●●○○○○○	122	107
●●●●●○○○○	122	118
●●●●●●○○○	122	126
●●●●●●●○○	122	132
●●●●●●●●○	122	136
●●●●●●●●●	122	150

Appendix B Instructions[21]

Introduction

Welcome! You are participating in an experiment to collect data for a scientific research.

During the experiment you have to make decisions that will contribute to determine a payoff, that will be paid cash at the end of the experiment.

The experiment is totally anonymous: neither the experimenters nor other participants will be able to associate your decisions to your identity.

During the experiment, your interactions with other participants will be intermediated by a computer. Any form of communication between participants is prohibited. If you violate this rule, you will be excluded from the experiment with no payment.

If you have any doubt about the experiment, raise your hand and an experimenter will come to answer to your question, privately.

The experiment consists of a sequence of several phases. For each of phase, you will receive specific instructions.

All the decisions you will take in each phase will contribute to your final payoff. In some phases your payoff depends only on your own decisions, while in others it depends on your decisions and on the decisions of other participants, as it will be explained later on.

Your payoff in each phase and your final payoff are expressed in an experimental currency called *Zed*. Your final payoff in Zed will be converted into a final payment in Euros, at the exchange rate of 20 Zed = 1 Euro.

Phase 1

In this phase you will be asked to answer to 13 questions. Every question has four possible answers, and your task is to choose the correct answer. For every question there is only one correct answer. You must answer the questions on your own and your payoff depends only on your choices. For each correct answer you will receive 1 point whereas for any wrong answer you will lose 1/2 points.

The questions will appear sequentially on your screen, and for each question you have 90 seconds to answer. If you do not provide any answer within the given time, that question will be considered as unanswered and you will not gain nor lose any point. Please note that once provided, your answer cannot be changed.

At the end of this phase, the computer screen will summarize: your own answers, the correct answers and the points you gained.

Your payoff in Phase 1

Your payoff in this phase depends on your answers to the questionnaire and on a binary lottery that guarantees a prize of 150 Zed or of 50 Zed.

[21] This represents a translation of the instructions used in the experiment for the groups of five depositors. The actual instructions are in Italian.

The total points obtained from the questionnaire will determine the probability of winning the prize of 150 Zed. This probability cannot be lower than 0 nor greater than 1, and it increases with the points obtained. Recall that the probability of gaining the prize of 50 is one minus the probability of gaining the prize of 150.

If all your answers are wrong, your score from the questionnaire is $(-1/2) \times 13 = -6.5$ and the probability of the prize of 150 is equal to 5%: this is the lowest probability with which you can win the high prize (150 Zed). In this case, the probability of the prize of 50 Zed is equal to 95%.

On the other hand, if all your answers are correct, then your score is $1 \times 13 = 13$ and the probability the prize of 150 Zed is 95%: this is the highest probability with which you can win the high prize. In this case, the probability of the prize of 50 Zed is equal to 5%.

For any other score, you will win the prize of 150 Zeds with a probability between 5% and 95%.

The lottery draw over the two prizes will be performed at the end of the experiment and the prize will be part of your final payoff.

For your convenience, we are providing you with a blank table that you can use to take note of the results of the questionnaire.

Phase 2

Let us now move to Phase 2.

An experimenter will read aloud the instructions of this phase. If you have any question, please raise your hand and an experimenter will come to answer your question, privately.

Recall that communication between participants is prohibited. If you violate this rule, you will be excluded from the experiment with no payment.

Your task in Phase 2

In this phase, you and other 4 participants will be randomly and anonymously selected to constitute an experimental bank.

Every member of the bank owns 100 Zed deposited in the experimental bank. Hence, a bank is composed of 5 depositors, whose identity is unknown to each other.

As a depositor, you have two options: you can either withdraw your 100 Zed and close your deposit account; or you can leave your money deposited in the bank.

How much you receive in either case depends jointly on how much the bank promises to repay and on the decisions of the depositors at your bank, who face your identical task.

The bank promises to repay 150 Zed to every depositor who decides not to withdraw his money and 122 Zed to every depositor who decides to withdraw. However, the bank may not be able to fullfil her promises if too many depositors decide to withdraw. Table 11 lists the payoffs you obtain depending on your choice and on the choices of all other depositors in your bank.

The bullets in the first column represent the possible decisions of the depositors at your bank other than you. In particular, the white bullet represents a depositor who decided to withdraw

Table 11: Payoff Table

	Payoff if you withdraw ○	Payoff if you do not withdraw ●
○ ○ ○○	98	7
● ○ ○○	122	90
● ● ○○	122	117
● ● ●○	122	132
● ● ●●	122	150

and close his deposit. The black bullet, on the contrary, represents a depositor who decided not to withdraw.

Example 1. Suppose that all depositors other than you withdraw. As the table shows, if you withdraw your payoff is 98 Zed. If you do not withdraw, your payoff is 132 Zed (see the first row of the table).

Example 2. Suppose that 3 depositors other than you decide not to withdraw. As the table shows, if you withdraw your payoff is 122 Zed. If you do not withdraw, your payoff will be 7 Zed (see the fourth of the table).

Why can't the bank always guarantee the promised repayments? Imagine that once the experimental bank has been constituted, the total deposits of 500 Zed are invested and that it takes time to generate a return.

To repay a depositor who decides to withdraw, the bank has to prematurely liquidate part of the investment. Those who do not withdraw are paid with the resources left after having repaid those who withdraw. Since premature liquidation is costly, if too many depositors decide to withdraw the bank cannot guarantee the promised repayments.

At the time you make your choice, the decision of the other depositors is unknown to you. Since any form of communication is forbidden, you are not allowed to ask to other participants their choice.

Procedure for Phase 2

Phase 2 consists of 20 periods. Each period is independent and completely separate from the others. In every period you will perform the task described in the previous section.

In each period, several experimental banks will be constituted, and each of them is completely separate from the others. Depositors are randomly assigned to an experimental bank. Therefore, you will meet with different depositors in every period. We cannot exclude that you will meet the same depositor more than once. However, the assignment to an experimental bank is completely anonymous, hence it is not possible for you to identify the other depositors.

At the beginning of each period you will have 100 Zed deposited in your experimental bank. As a preparation to your main decision, you will be asked to state your expectations about how many depositors of your bank other than you will withdraw, and about how many will leave their money deposited in the bank. Note that the sum of these two numbers has to be equal to 4 (four).

Then, you will have to decide whether to withdraw or not your deposit. You have 30 seconds to take your decision. If you have not made any decision within the time limit, the computer will randomly select your decision.

At the end of each period your decision, your payoff and the number of withdrawals at your bank will be privately communicated to you.

Computer Instructions

During phase 2, three different screens will appear on your computer: preliminary, decision and report screens.

The preliminary screen gives you information about the experimental bank you have been assigned to.

The decision screen is shown in Figure 7.

Figure 7: Decision Screen

Period 1 out of 20

	Payoff if you withdraw ○	Payoff if you do not withdraw ●
○○○○	98	7
●○○○	122	90
●●○○	122	118
●●●○	122	132
●●●●	122	150

WITHDRAW | DO NOT WITHDRAW

Time left to decide

The decision screen shows the payoff table as described above. It shows the two buttons that you will have to press to take your decision.

Once you press a button, you cannot change your choice.

At the top of the screen, the current period is displayed. At the bottom, there is countdown bar showing the time left to take you decision.

After all depositors in your bank have taken their decisions, a report screen will provide information about: your decision, your payoff and the number of depositors who decided to withdraw in the current period. You have 10 seconds to read those information before the new period starts.

Your payoff in Phase 2

Your payoff for Phase 2 will be determined by random selection of one period out of the 20 ones. The draw will be performed at the end of the experiment and you will be assigned the payoff corresponding to the selected period.

Phase 3

An experimenter will read aloud the instructions of this phase. If you have any question, please raise your hand and an experimenter will come to answer your question, privately.

Recall that communication between participants is prohibited. If you violate this rule, you will be excluded from the experiment with no payment.

In this phase 10 (ten) pairs of binary lotteries will be displayed on your screen. For each lottery, you will find on the screen the value and the probability of each prize. Your task is to choose one lottery within each pair. Your choice will determine your payoff for this phase as described below.

Your payoff in Phase 3

At the end of the experiment, one of the ten lottery pairs will be randomly chosen. Right after, the lottery you chose within the selected pair will be played by your computer. The prize extracted will determine your payoff in Zed for this phase.

Concluding the experiment

This phase is devoted to determine your total payoff, that is the sum of the payoffs you gained in each phase of the experiment.

We start with Phase 1. The computer will summarise on your screen: your answers to the questionnaire, the correct answers, your total score, and your probability to win the prize of 150 Zed. The lottery draw will be visualised on your computer and it will determine your payoff for Phase 1.

As for Phase 2, one period out of the 20 will be randomly chosen. The random draw is common to all participants. At this stage, the computer screen will summarise your payoffs for every period of Phase 2.

As for Phase 3, we will select one of the ten pairs of lotteries through a random procedure. Subsequently, the computer will play the lottery you choose within the selected pair. The prize visualised on your computer will determine your payoff for Phase 3.

The sum of all payoffs will determine your final payoff expressed in Zed. This payoff will then be converted into euro according to the predetermined exchange rate of 20 Zed = 1 Euro, and this amount will constitute your final payment for the experiment.

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