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Communication and group size on bank run games

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ABSTRACT

This study examines the impact of communication and group size on bank run games, with a strategic focus on three-player games. In the baseline treatment group, communication is not allowed in two-player and three-player games. The main treatment consists of costless communication, cheap communication, and costly communication. The sender's action becomes more predictable with the increasing communication costs due to a lack of incentives to deceive. We find that in the non-cooperative, two-player bank run game, communication fosters cooperative behavior with the learning effect in the repeated interaction. However, coordination is far more difficult to achieve with Nash Pareto dominant equilibrium in three-player games due to its complexity in decision-making in larger groups. The ultimate result presents the limitation of communication as an efficiency-enhancing mechanism. A public recommendation is that policymakers should increase public transparency and ensure public confidence in banking systems to mitigate the risks and uncertainty of bank runs. In sum, the study presents the following:

- In a three-player bank run game, communication is less effective than in a two-player scenario.
- Policymakers should ensure public confidence and increase public transparency of banking systems.

Specifications table

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Method details

Our model builds on and refines the framework introduced by Cooper et al. [3] in several ways. First, we extend the pre-play communication and coordination game within the context of bank runs. In our experimental design, we believe that communication conveys a useful signal to other players in their decision-making process. Regarding pre-play communication, it is no longer merely cheap talk. In other words, we evaluate the effects of both cheap and costly communication. We offer three types of communication: *Costless, Cheap, and Costly*. In this case, if communication is *Costless*, then the communication cost is zero. If communication is Cheap, then the player is charged 20 points to send a message. For Costly communication, the level of communication costs can be 50 points,

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80 points, or 100 points. For simplicity, we providethe sender with an endowment of extra points in the games so that payoff matrices remain consistent throughout the experiments.

Secondly, we consider a more realistic communication mechanism design called restricted communication. There are some debates about one-way communication versus two-way communication. Cooper et al. [3] find that two-way communication is more effective in achieving the Pareto dominant Nash Equilibrium than one-way communication in coordination games. Specifically, in a two-by-two game with a trade-off between Pareto efficiency and risk dominance, one-sided communication makes it more likely to reach the efficient equilibrium to some extent, while two-sided communication ensures reaching efficiency.

However, we argue that two-way communication can create confusion when players send different messages. Vespa and Wilson [4] consider a cheap-talk environment with multiple senders, and they find a failure of sequential rationality. One-way communication offers advantages over two-way communication. Restricted communication can avoid the problem of over communication that may arise when both players have a chance to send messages [5]. For example, one-way communication can produce a more efficient outcome of games than two-way communication because it creates the opportunity for the sender to establish centralized authority. When a player is selected to send a message, we expect that players will be more likely to cooperate. In the context of communication structure design, we do not allow any free form of communication, so the sender will therefore only send the message *Wait* or *Withdrawal* in the play. *Wait corresponds to* later fund withdrawal, while *Withdrawal corresponds to* early fund withdrawals. Indeed, there is no significant difference in the equilibrium outcome whether communication is restricted or not [6]. It is also important to note that senders are non-binding to send a message. Therefore, we will solely focus on one-way communication rather than two-way communication in this paper.

Lastly, much of the existing literature in pre-play communication and coordination games such as Kim et al. [7] has predominantly focused on a two-player game, so we expand the scope by exploring a three-player game in this study and comparing the results with the two-player game scenario. A few studies focusing on the three-player games have different designs. For example, Cason et al. [8] studied the three-player game in a competitive game with a focus on inter-group and intra-group communication. Grandjean et al. [9] focused on the communication structure and credibility in three-player games. In our paper, we design a restricted communication structure and varying levels of communication treatments in both two-player games and three-player games. We believe this study can be helpful to explain and observe complex human behavior in real life.

The experimental design

In this experiment, there will be two rounds: Round A and Round B. The order of our treatment conditions does matter, so we use a between-subjects design for this experiment. Each subject will be randomly assigned to only one treatment condition. The game may be repeated over several periods and may involve endogenous bank runs in any period. If a bank run occurs, then you and your opponent's payoffs are zero in that period. Both players have the choice to withdraw their funds in each period. The game's payoffs depend on the coordination of their decisions. I assume that players satisfy the following underlying assumptions:

Assumption 1. Each player will not know what the other player do. In other words, each player makes actions independent of each other.

Assumption 2. Players are rational and self-interested agents in the games to maximize their payoffs based on the information available to them.

Assumption 3. Players are unable to implement strategies that are too complex.

Assumption 4. All players are inexperienced and will learn how to play the game.

In Round A, players will play two-player games, while in Round B, they will play three-player games. It is important to note that all players have equal chances to be Player A or Player B. Once the type is determined, it will not change for the rest of the games. This also holds for the sender. For example, if a type A player is chosen as a sender, this will remain the same throughout the game.

Duffy and Ochs [10] discovered that a fixed matching protocol is more likely to form cooperative behavior than a random pairing protocol; when groups are fixed over time, it will be much easier to achieve improved coordination outcomes [11]. However, consider the realistic scenario where not all individuals consistently play with the same group, so we take a random matching protocol in the experiment. Each player will always be randomly matched with a different player in each period of the game.

In the first part of Round A, two players are not allowed to chat or communicate and they will make the decisions simultaneously. In the second part, communication between players is allowed and a chat box will appear. This communication is optional and one-way, with a communication cost is zero (c=0). In the third part, the communication is introduced as cheap and one-way with a communication cost (c=20). This means that sending a message results in a 20-point deduction from your payoff, while receiving the message does not incur any additional costs. In the last part, the communication will become costly, with levels of costs of 50 points, 80 points, and 100 points (c=50, 80, 100). If a player is selected as the sender, they will receive extra points as an endowment to cover the cost of communication.

In Round B, there will be three players A, B, and C, and each player has an equal chance to be randomly chosen as Player A, B, or C. Once the type is determined, it will not be changed for the rest of the games. For example, if a type A player is chosen as a sender, this will remain the same throughout the game.

In the first part, there is no communication, and all players simultaneously make decisions. In the second part, one-way communication is permitted at no cost (c=0). The third part introduces one-way communication for 20 points (c=20). In the last part, the

Table 1
Two-player bank runs game.

		Player B	
		Early	Late
Player A	Early	(400,400)	(600,150)
	Late	(150,600)	(800,800)

communication will be costly, with cost levels of 50 points, 80 points, and 100 points (c=50, 80, 100). Similar to Round A, if a player is selected as the sender, they will receive extra points as an endowment to cover the cost of communication.

Treatment Groups	
Round A	
1	Two players without communication (Baseline)
2	Two players with costless communication
3	Two players with cheap communication
4	Two players with costly communication (Various Levels)
Round B	
1	Three players without communication (Baseline)
2	Three players with costless communication
3	Three players with cheap communication
4	Three players with costly communication (Various Levels)

Experimental procedures

In this section, we explain the experimental procedures for the experiment on decision-making in economics. Subjects are required to complete all sessions. There will be a total of six sessions consisting of Round A and B. In the first three sessions, subjects will be playing the Round A. In the last three sessions, they will be playing Round B. The total sessions will last about 1 h and 30 min to 2 h. The programming software used for the experiment is oTree.

Before the experiment, subjects will be instructed on how to play the games and take the quiz. Your payment depends on your decisions and decisions of other players. All players will play several rounds before the start of the experiment. In the first session of Round A, two randomly matched players will be playing the baseline treatment and costless communication treatment. They will be playing cheap communication treatment in the second session. In the third session, they will be asked to play costly communication treatment. All subjects have equal chances to either be Player A or Player B. It is important to note that the play is repeated and each treatment will be played in 10 periods. Subjects are expected to see their payoffs on the screen as shown in Table 1. In the communication treatment, the sender will decide whether to communicate or not. If not, he/she will keep endowments for himself/herself. If so, the communicator will spend the endowments and send a message whether Wait or Withdrawal in the chat. Receiving the message is free.

In Round B, for the last three sessions, all subjects have equal chances to be Player A, Player B, or Player C. In the first session of Round B, three randomly matched players will be playing the baseline treatment and costless communication treatment. Then they will play cheap communication treatment in the second session. In the last session, they will be asked to play costly communication treatment. Each treatment group will be played for 10 periods. They are expected to see their payoffs on the screen as shown in Table 2. In communication treatment, if a sender is selected, then a message about whether Wait or Withdrawal can be sent out to the group. After the experiment, subjects have to fill out a short questionnaire asking for their demographic information.

Adaptive learning model

In this section, we aim to construct an adaptive learning model that describes how players learn and update their strategies over time through playing the game. Since we focus on how players update their beliefs as the game progresses, a belief-based learning model is constructed to predict the theoretical predictions.

Differing from Blume et al [1], I model the receiver's action as a function of the sender's past action when communication is allowed; otherwise, this relationship may not hold. In other words, receivers may update or change their actions by observing the actual past actions of senders. When the sender enables the communication, receivers gain the ability to predict the actions of the

Table 2
Three-player bank run game.

The Bank Runs Game in Normal Form: payoffs are color-coded: **Player A**, **Player B**, **Player C**		Player C			
		Early		Late	
		Player B		Player B	
		Early	Late	Early	Late
Player A	Early	400,400,400	600,150,600	600,600,150	600,150,150
	Late	150,600,600	150,150,600	150,600,150	800,800,800

Due to the complexity of a three-player game, I break it into a more straightforward version for players.

If Player C plays Early,

		Player B	
		Early	Late
Player A	Early	400,400,400	600,150,600
	Late	150,600,600	150,150,600

If Player C plays Late,

		Player B	
		Early	Late
Player A	Early	600,600,150	600,150,150
	Late	150,600,150	800,800,800

sender. The senders' actions become more predictable along with the increasing cost of communication because they have no strong incentives to deviate. The focus then turns to understanding the interplay between receivers and senders and their strategies in the game.

In the two-player game, let A be the matrix representing Player A, and let B be the matrix representing Player B, where A and B are both $n \times 1$ column matrices.

$$A = \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_n \end{bmatrix}, \; B = \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_n \end{bmatrix}$$

If player A is chosen as a sender, let A_t denote the action of the sender and Player B be a receiver.

Then its mathematical expression is $B_t = f_t(A_{(t-1)}, \; A_{(t-2)}, \ldots, A_{(t-k)})$, where B_t is the player B's action; $A_{t-1}, \; A_{t-2}, \ldots, A_{t-k}$ represents the past actions of player A; the function f_t represents the function of the receiver's action as the sender's past actions. Finally, the index t denotes the period of the game.

Represent this model in a matrix form:

$$\begin{bmatrix} B_{t1} \\ B_{t2} \\ \vdots \\ B_{tn} \end{bmatrix} = \begin{bmatrix} f_{t1}\left(A_{t1}, A_{(t-1)1}, \cdots, A_{(t-k)1}\right) \\ f_{t2}\left(A_{t2}, A_{(t-1)2}, \cdots, A_{(t-k)2}\right) \\ \vdots \\ f_{tn}\left(A_{tn}, A_{(t-1)n}, \cdots, A_{(t-k)n}\right) \end{bmatrix} \tag{1}$$

In the three-player game, let A be the matrix representing Player A, let B be the matrix representing Player B, and let C the matrix representing Player C,

$$A = \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_n \end{bmatrix}, \; B = \begin{bmatrix} B_1 \\ B_2 \\ \vdots \\ B_n \end{bmatrix}, C = \begin{bmatrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{bmatrix}$$

where A, B, and C are both $n \times 1$ column matrices.

In this new case, if player A is chosen as a sender, then let A_t denote the action's sender. Player B and Player C be two receivers. The new model in the matrix forms:

$$\begin{bmatrix} B_{t1} \\ B_{t2} \\ \vdots \\ B_{tn} \end{bmatrix} = \begin{bmatrix} f_{t1}\left(A_{t1}, A_{(t-1)1}, \cdots, A_{(t-k)1}\right) \\ f_{t2}\left(A_{t2}, A_{(t-1)2}, \cdots, A_{(t-k)2}\right) \\ \vdots \\ f_{tn}\left(A_{tn}, A_{(t-1)n}, \cdots, A_{(t-k)n}\right) \end{bmatrix}$$
$$\begin{bmatrix} C_{t1} \\ C_{t2} \\ \vdots \\ C_{tn} \end{bmatrix} = \begin{bmatrix} h_{t1}\left(A_{t1}, A_{(t-1)1}, \cdots, A_{(t-k)1}\right) \\ h_{t2}\left(A_{t2}, A_{(t-1)2}, \cdots, A_{(t-k)2}\right) \\ \vdots \\ h_{tn}\left(A_{tn}, A_{(t-1)n}, \cdots, A_{(t-k)n}\right) \end{bmatrix} \tag{2}$$

f represents the function of the receiver B's action as a function of the sender A's past action. Similarly, h respresents the function of receiver C's action as a function of the sender A's past action.

The relationship between two matrices defined in Eqs. (1) and (2) is straightforward. The matrix in Eq. (1) represents the adaptive learning model in a two-player game, where there is only one sender and one receiver. However, the matrix in Eq. (2) represents the adaptive learning model in a three-plater game, where there exists one sender and two receivers. Both matrices capture how the sender's past action influences the receiver's action.

Statistical analysis

In our analysis, we refine the model proposed by Kriss et al [2] by including group size variable in our model.

We want to study how the communication, group size, and learning effect will influence the frequency of selecting an efficient coordination game. In our methodology, we will employ logistic regression models. Let u=P(Y=1|X)=P (success given covariates values). The base groups consist of no communication treatment and a two-player game.

Our models are as follows:

$$\begin{aligned} \log\left(\frac{u}{1-u}\right) = \beta_0 + \beta_1 \times Costless\ Communication + \beta_2 \times Cheap\ Communication + \beta_3 \\ \times Costly\ Communication + \beta_4 \times Three - player + \ \beta_5 \times Period + FE\ Controls, \end{aligned} \tag{3}$$

where $\log(\frac{u}{1-u})$ is the probability of selecting the efficient outcome in the game; Costless Communication is a dummy variable equal to 1 if the sender chooses to chat in the costless communication treatment group; Cheap Communication is a dummy variable equal to 2 if the sender chooses to chat in the cheap communication treatment group; Costly Communication is a dummy variable equal to 3 if the sender chooses to chat in the costly communication treatment group; Three-player is a dummy variable equal to 1 if there are three player in the game; Period is a continuous variable that records all rounds of the game; FE Controls are the fixed effects for heterogeneity of players. β_0 represents the intercept of model (3), while β_1,..., β_5 represents the coefficients of these covariates.

For simplicity, assume that no communication in a two-player game is observed in period 1, then we have $\log(\frac{u}{1-u}) = \beta_0 + \ \beta_5$ (3). The $\log(\frac{u}{1-u})$ is the log odds *ratio*, so the odds ratio will be $e^{\beta_0+\beta_5}$. Then a 95% confidence interval for the odds ratio is $(e^{\beta_0+\beta_5-1.96se(\beta_0+\beta_5)}, e^{\beta_0+\beta_4+1.96se(\beta_0+\beta_5)})$. The interpretation is that if the odds ratio is not included in the confidence interval, we are 95% confident that the odds ratio is not equal to 1, which suggests that the covariates do influence the response variable.

The probability of selecting an efficient outcome from model (3) is as follows: $P(Y = 1|X) = \frac{e^{\beta_0+\beta_5}}{1+e^{\beta_0+\beta_5}}$

We also consider a variant of the model, which includes the interaction terms between Communication and Period because it may allow us to capture how the dynamic effects between communication and period.

$$\begin{aligned} \log\left(\frac{u}{1-u}\right) \beta_0 \ + \ \beta_1 \times Costless\ Communication + \beta_2 \times Cheap\ Communication + \beta_3 \\ \times Costly\ Communication + \beta_4 \times Three - player + \ \beta_5 \times Period + \ \beta_6 \times (Cheap\ Communication\ \times\ Period) \\ + \beta_7 \times (Costly\ Communication\ \times\ Period) + FE\ Controls \end{aligned} \tag{4}$$

where the interaction term (Cheap Communication × Period) measures the effect of Cheap Communication also depends on the period; the interaction term (Costly Communication × Period) measures the effect of Cheap Communication also depends on the period; $\beta_0$represents the intercept of model (4), while β_1,..., β_7 represents the coefficients of these covariates.

To determine if we need to add them, we will perform a LR test (Likelihood ratio test).

$$H_0 : \quad \beta_6 = \beta_7 = 0$$

H_a : H_0 is not true or at least one of them is not zero.

If the p-value is less than 0.05 significance level, we have evidence to conclude that both interaction terms should be kept in model (4). Therefore, model (4) is considered to be a better one compared to model (3).

In model (4), if we assume that a cheap communication treatment in a two-player game is observed in period 1, then we have $\log(\frac{u}{1-u})=\beta_0 + \beta_2 + \beta_5+ \beta_6$. The $\log(\frac{u}{1-u})$ is the log odds ratio, so the odds ratio will be $e^{\beta_0+\beta_2+\beta_5+ \beta_6}$.

Then a 95% confidence interval for the odds ratio is $(e^{\beta_0+\beta_2+\beta_5+ \beta_6-1.96*se(\beta_0+\beta_2+\beta_5+ \beta_6)}, e^{\beta_0+\beta_2+\beta_5+ \beta_6+1.96*se(\beta_0+\beta_2+\beta_5+ \beta_6)})$. The interpretation is that if the odds ratio is not included in the confidence interval, we are 95% confident that the odds ratio is not equal to 1, which suggests that the covariates have an impact on the response variable. The probability in model (4) can be computed as follows: $P(Y=1|X)=\frac{e^{\beta_0+\beta_2+\beta_5+ \beta_6}}{1+e^{\beta_0+\beta_2+\beta_5+ \beta_6}}$.

Conclusion and discussion

The failure of Silicon Valley Bank reflects the importance of understanding the bank run literature, particularly in the context of financial distress experienced by regional banks. In this paper, we investigate the effect of communication and group size on the bank run games.

We find that in the non-cooperative, two-player bank run games, communication fosters cooperative behavior with the learning effect in the repeated interaction. That said, communication can change the dynamics of a two-player game to encourage cooperative behavior as players get more experience over time. The adaptive learning model presented reveals that the sender's action will be more predictable with the increasing communication cost due to a lack of incentives to deviate. When senders disclose their private information through communication, the other player will be more experienced in his/her own and senders' strategies.

However, communication also can be shown to have a destabilizing role in the coordination of bank runs in a larger group size. In other words, coordination is far more difficult to achieve with Nash Pareto dominant equilibrium in three-player games due to its complexity in decision-making in larger groups. Here is the analysis: even if we assume that the sender's action is more predictable along with the increasing cost of communication, it is very difficult for two receivers to coordinate no bank run outcome when their private information is not disclosed.

This study shows that communication as an efficiency-enhancing mechanism can solve coordination failures in bank runs when the group size is relatively small. In other words, communication may not be effective in helping coordinate no bank run outcome due to its greater complexity in decision-making in a large group of players.

This paper also has several recommendations for policymakers. First, in addressing the vulnerability of the banking system, financial regulations should take more stringent oversight and stress testing. For example, it is imperative to implement laws that mandate regular financial reporting by the banking industry to support the stability of banking systems. Second, to improve coordination in larger groups, the policymakers should increase public transparency and ensure public confidence in banking systems to mitigate the risks and uncertainty of bank runs. For example, it is essential to open effective communication channels between financial institutions and depositors or investors. Future research endeavors in this area are both necessary and advisable.

Ethics statements

Not Available.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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