Crisis Bargaining with Collective Decision Making*

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Abstract

Crisis bargaining games are widely used to analyze bilateral conflicts, featuring strategic bluffing akin to poker. Players risk substantial losses from overplaying their hand but can secure significant gains if their opponent concedes. Since decisions in crises typically emerge from collective decision processes within organizations composed of diverse individual members, we use the *team equilibrium* solution concept to analyze these games, providing a framework for group strategic decision-making under collective choice rules (Kim et al. (2022)). In team equilibrium, group members have rational expectations about opponents' strategies and share common average payoffs, with private payoff perturbations. Voting rules determine group decisions, assuming optimal voting behavior. Depending on the payoff structure, collective choice rules can lead to more or less bluffing and varying aggression compared to Perfect Bayesian Equilibrium. Our experiment varies game payoffs, group size, and voting rules. Behavior is inconsistent with Perfect Bayesian Equilibrium but broadly consistent with team equilibrium predictions.

JEL Classification: C72, C92, D71, D82
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"Treating national governments as if they were centrally coordinated, purposive individuals provides a useful shorthand for understanding problems of policy. But this simplification - like all simplifications - obscures as well as reveals. In particular, it obscures the persistently neglected fact of bureaucracy: the 'maker' of government policy is not one calculating decision maker but is rather a conglomerate of large organizations and political actors."

—Graham Allison, *Essence of Decision, p. 3*

1 Introduction

In one of the most famous and influential political science books of the last century, *Essence of Decision*, Allison (1971) convincingly attacks the unitary actor paradigm of decision-making in international relations and proposes that more realistic approaches should analyze crisis situations by taking account of frictions that arise because the decision makers are teams rather than individuals. Allison's book is a case study of the Cuban Missile Crisis, which occurred in the early years of President John F. Kennedy's administration, when the government of the Soviet Union, led at the time by Nikita Khrushchev, secretly began installing ballistic missiles in Cuba. The book documents how the decision-making team in the Kennedy administration coalesced on a response to this threat. The crux of the argument in the book, illustrated with the case study, is that while it may be plausible to model decisions by individuals as rational, applying the same single-agent rationality model of decision-making to teams cannot be justified.[1] Allison proposes two alternatives to the unitary rational actor model, one of which emphasizes collective choice processes and procedural constraints ("The Organizational Process Model") and the second which emphasizes the heterogeneous idiosyncratic preferences and biases of the individual members of the decision-making organization ("The Governmental Politics Model").

The Allison critique of the unitary rational actor model extends far beyond applications to national security policy and international relations. Similar dynamics arise in many strategic conflicts in economic environments, where decision-making units are not single actors but organizations, i.e., groups of individuals working toward shared goals while also navigating idiosyncratic private objectives. These groups operate collectively under specific

[1]Allison's insight has been shown to be far-reaching, as evidence about differences between team and individual behavior has accumulated from laboratory experiments in economics and psychology over the last several decades in a wide range of strategic games and decision problems. See Charness and Sutter (2012) for a survey of some of this evidence.

organizational procedures and constraints, which shape their decisions. For example, during union and firm negotiations over contract amendments or extensions, union members often vote on strike authorizations, reflecting diverse preferences within the membership. While all members share the same broad objectives, generally favor improved working conditions, higher wages, and better benefits, they differ in their willingness to bear the costs and risks of striking. Votes to accept or reject negotiated contracts highlight this internal diversity. Firms, too, are rarely unitary actors; they are typically large corporations, governmental entities, or even coalitions in cases of industry-wide collective bargaining.

To understand inter-group bargaining processes such as these, it is necessary to take the Allison critique seriously and model the diversity of preferences as well as the collective decision-making mechanism by which those preferences are aggregated into a decision within each group. A theoretical framework specifically designed for this purpose, called *team equilibrium* was developed in Kim et al. (2022). In a team equilibrium, group members have rational expectations about opponents' strategies and share common average payoffs, but have idiosyncratic, privately observed payoff perturbations, modeled as additive, mean zero, i.i.d. random disturbances for each team strategy, for each team member. That is, each member of the same team has the same expected payoff for a team action *on average*, plus an unbiased additive disturbance term. The common component of team member expected payoffs captures the fundamental alignment of team member preferences that make them a 'team', a group of individuals with a common interest, while the i.i.d payoff perturbations model the team member heterogeneity that makes collective decision making non-trivial.

The second element of team equilibrium is the voting rule used by teams to select a team decision. In a team equilibrium, given average expected payoffs for each strategy and team member payoff perturbations, each team member votes optimally, given the expected (equilibrium) payoffs of each strategy and their own idiosyncratic payoff disturbances. The voting rule then aggregates votes into one collective decision. Thus, team equilibrium incorporates the key features of the Allison critique. It allows for heterogeneity of preferences among team members, i.e., in the language of Allison it is a *bureaucratic politics model*, and it explicitly models the collective decision making procedure, i.e., it is an *organizational process model*. Understanding the interaction of these two characteristics of teams is crucial for understanding the behavior of teams, and how teams differ from individual decision makers.

This paper investigates, theoretically and experimentally, a class of simple crisis bargaining games that model the subsequent stages of international crises like the Cuban missile crisis, where, after a threat by one country, a second country decides to acquiesce or escalate the conflict, in anticipation of the responses by the instigator of the crisis. The instigator, in the event that the threatened country fights, makes inferences about the military strength and resolve of the threatened country and decides whether to carry out the threat, resulting in either a military conflict, or back down. This is formally modeled as a very simple bluffing game, taking as given that the threat has already occurred.[2]

The threatened country is the *first mover*, called Player 1, and has private information about their own strength, and decides whether to escalate or acquiesce. The instigator is the *second mover*, called Player 2, and responds to an escalation by either engaging the fight or backing down. If the fight is engaged, then the instigator loses (wins) if the threatened country is strong (weak).[3]

These crisis bargaining games are characterized by four parameters: the probability the threatened country is strong; the *concession payoff*, a, gained by a player if the other player acquiesces or backs down (and an equivalent loss, $-a$, to the other player); the *(sender) risky payoff*, s, (or loss, $-s$) to Player 1 if there is a fight and they win (lose); the *(receiver) risky payoff*, r, (or loss, $-r$) to Player 2 if there is a fight and they win (lose).

Our experiment compares the behavior of 5-person teams operating under two different decision collective choice rules - majority rule and unanimity rule. We obtain data for four different payoff variations of crisis bargaining games and also run a parallel series of sessions with 1-person teams. We fix the concession payoff and the probability of a strong Player 1 (0.5) for all four games and only vary the two risky payoffs.

The natural benchmark that guided our choice of four payoff treatments is Perfect Bayesian Equilibrium (PBE), which uniquely pins down the fight probabilities for each player. In these games the strong Player 1 has a dominant strategy to fight; the weak Player 1 bluffs by choosing to fight with a probability strictly between 0 and 1; if Player 1

[2]The crisis bargaining model also applies directly to the union-firm negotiation example, with the players of the game having threat options such as strikes, lockouts, or violence, and each party responds to the other as the sequence of actions unfolds, with the potential for further escalation. Each party also has the option of acquiescing to the terms offered by the opposing party. There are a variety of other economic applications, for example legal conflicts involving lawsuits and countersuits, or negotiations over plea agreements in criminal cases.

[3]Such games are sometimes referred to as "simplified poker games". The "simple card game in Myerson (1991, Figure 2.1, p. 38) is one example. The class of games also corresponds to the last two stages of the canonical crisis bargaining game form in Fearon (1994b) [Figure 2, p.241]

chooses to fight, then Player 2 responds by backing down with a probability strictly between 0 and 1. Thus, it is a classic bluffing game where PBE mixed strategies are such that the weak Player 1 and Player 2 are both indifferent between fighting and backing down. The payoff variations chosen for the experiment span the four canonical PBE mixing probabilities. In one payoff treatment, both players' PBE fight probabilities are greater than 0.5; in a second payoff treatment, both are less than 0.5; and in the other two payoff treatments, one of the player's PBE fight probabilities is greater than 0.5 and the other's is less than 0.5. This four-payoff design allows clear comparative static predictions of the equilibrium effect of changing payoffs, based on PBE.

All decisions in these games are binary (fight vs. acquiesce for Player 1, fight vs. back down for Player 2), so the voting process with 5-person teams is straightforward. All team members cast simultaneous independent votes when it is their team's turn to make a decision. In the 5-person teams under majority rule, a team's decision is to fight if and only if at least three of the team members vote to fight; with unanimity rule, a team's decision is to fight unless every team member votes *not* to fight.[4] In the 1-person team, the single member's decision is binding, as in a typical 2-person game experiment, without any voting.

Similarly to the PBE, the team equilibrium is defined in terms of the fight probabilities of the teams deciding for each player - strong Player 1 (p_{1S}), weak Player 1 (p_{1W}), Player 2 (p_2) - but with the two additional effects of the random payoff disturbances and the collective choice rule. Formally, a team equilibrium is a solution to the following fixed point problem. Consider any possible team decision probabilities, $p = (p_{1S}, p_{1W}, p_2)$. This in turn implies expected payoffs for fighting or acquiescing for each type of Player 1 and for Player 2. Given these expected payoffs, the distribution of random payoff perturbations implies vote probabilities for each member of each team, which in turn, depending on how the voting rule aggregates votes into team decisions, imply a profile of team decision probabilities, $p' = (p'_{1S}, p'_{1W}, p'_2)$. We define p to be a team equilibrium if and only if $p' = p$.

The results of the experiment have four main takeaways. First, the data clearly reject the predictions of PBE. In fact, a purely random model, which disregards payoff effects and predicts that weak Player 1 and Player 2 will each choose IN or OUT with equal probability across all game variations, actually fits the data better than PBE. Second, outcomes in games

[4]The unanimity rule is asymmetric. The opposite version of unanimity, which we did not study would have the team decision as fight if and only if all members voted to fight.

played by groups are not closer to PBE than outcomes in games played by individuals, but teams are "more rational" than individuals in the sense that they are more likely to make optimal decisions. Third, the collective choice rule matters; outcomes are significantly different for teams operating under majority rule and unanimity rule. Fourth, a one-parameter logit specification of the team equilibrium model explains the various patterns of behavior across treatments and provides a close fit to the aggregate data.

The rest of the paper is organized as follows. Section 2 explains the connection of our paper with several different literatures in political science and behavioral game theory. Section 3 introduces the class of crisis bargaining games used in the experiment, solves for the PBE as a function of the game parameters, and derives the equilibrium conditions for the (logit) team equilibrium with majority rule and unanimity rule. Section 4 describes the experimental design and procedures, identifies five key research questions that the experiment is designed to answer, and provides computational solutions of team equilibrium for all the treatments. Section 5 describes the results of the experiment and the estimation of the logit specification of the team equilibrium model.

2 Related Literature

The crisis bargaining games we employ in our study follow a longstanding tradition in political science of using these games to better understand the causes and resolution of international conflicts such as wars, and the role of threats, strategic deterrence, sanctions, alliances, and military interventions. Those studies, which all are in the unitary rational actor paradigm, include a combination of theoretical and empirical analysis. See for example Fearon (1994a), Fearon (1994b), Lewis and Schultz (2003), Signorino (1999), Morrow (1989), Smith (1995), Smith (1999).[5]

The current paper is connected to a recent and expanding body of literature that investigates experimentally the behavioral differences between teams and individuals in a wide range of game-theoretic and decision-making environments. See Kocher et al. (2020) and references therein.[6] The series of papers by David Cooper and John Kagel is the most closely

[5]The class of crisis bargaining games we study in this paper are similar to the final two-stage subgame of the of the crisis bargaining games analyzed in Fearon (1994b), Lewis and Schultz (2003), Signorino (1999), and Smith (1995). Signorino (1999) and Lewis and Schultz (2003) compare the properties of PBE and quantal response equilibrium in crisis bargaining games, which foreshadows the use of payoff disturbances in our team equilibrium framework, except they treat teams as unitary actors.

[6]See also Charness and Sutter (2012) and Kugler et al. (2012) for the early papers in economics that

related to our study. In Cooper and Kagel (2005), behaviors of individuals (1×1) and two-person teams (2×2) are examined by using the limit pricing game (Milgrom and Roberts (1982)). The team decision-making process unfolds as follows: both members are allotted three minutes to communicate and coordinate their actions. Once their choices align, and there is no alteration in decisions for four consecutive seconds, the team decision becomes binding. In cases where no coordination occurs within the three-minute time frame, one team member is randomly selected to implement their decision as the team's final decision. The authors demonstrate that teams exhibit greater strategic behavior compared to individuals. This is evident in their heightened ability to understand opponent players' incentives and responses, allowing them to adjust their behavior more effectively. As a result, teams are better at transferring their learning to games with different parameters, whereas individuals show no learning transfer between games.

Cooper and Kagel (2009) examine the differences in learning transfer between individuals (1×1) and two-person teams (2×2) in the limit pricing game by employing a similar design. In the experiment, the context is meaningful, for example, with players described as 'firms.' The framing changes as players are asked to choose either quantity or price against their opponent. A similar result is found, where teams consistently choose strategic behavior, while individuals exhibit limited learning across the games.

Although there have been many papers about groups playing games, an environment that corresponds to our design, in which team members vote for an action to determine the team's action, is scarce. One notable exception is Kim and Palfrey (Forthcoming), where behavior of games played by individuals (1×1) is compared to behavior with five-person teams (5×5) in variations of prisoners' dilemma and stag hunt games. Three collective choice procedures are studied: majority rule, majority rule preceded by a poll, and and majority rule preceded by chat. They find significant bandwagon effects that lead to consensus in majority rule preceded by a poll and chat. There are two main findings. First, in prisoners' dilemma games with relatively weaker incentives to defect, teams cooperate more than individuals, which is the opposite of finding from previous prisoners' dilemma experiments with teams. Second, in stag hunt games, teams consistently coordinate more frequently than individuals and, when coordination occurs, are more likely to achieve the payoff dominant outcome.

There is a growing experimental literature in political economy that examines the effect of

compare teams and individuals.

different voting rules in strategic environments. This includes several studies that compare the effects of majority and unanimity voting rules in legislative bargaining environments (Baron and Ferejohn (1989)). Miller and Vanberg (2013) compare majority and unanimity voting rules in three-person committees. Consistent with theory, they find that the size of coalitions tends to be larger under the unanimity voting rule, while it takes longer for the committees with the unanimity voting rule to reach agreements. Miller and Vanberg (2015) study those two voting rules with committees with different sizes. The finding indicates that while there is no difference in delays between small and large committees under the unanimity voting rules, the majority rule leads to more frequent delays in large than in small committees. In the presence of communication, Agranov and Tergiman (2014) and Agranov and Tergiman (2019) use majority and unanimity voting rules in five-person committees, respectively. While majority voting with communication aligns more closely with theoretical predictions, the unanimity voting rule produces more egalitarian outcomes and less frequent delays in reaching agreements.

In the dynamic public goods environments, Battaglini et al. (2012) compare the effects of majority and unanimity voting rules on investments in the public good. They find that the unanimity voting rule leads to higher investment in the public good than the majority voting rule, which is consistent with the theoretical predictions. Battaglini et al. (2020) examine a dynamic environment that permits lending and borrowing across periods and introduces uncertainty about the value of the future public good. The main finding concerning different voting rules is that the efficiency of public good provision increases with the number of votes required to accept the proposal.

Majority and unanimity rules have also been compared in laboratory experiments in order to understand strategic voting behavior in the information aggregation problem known as the Condorcet jury problem.[7] The first paper to study this application in the laboratory is Guarnaschelli et al. (2000), which compares the effect of voting rules between majority and unanimity, with different group sizes and with/without of straw polls. They find that voters under the unanimity voting rule are more inclined to vote strategically than under the majority voting rule. This effect of unanimity on strategic voting is significantly diminished when the group can communicate via a straw poll, leading to outcomes closer to those

[7] See Palfrey (2013) for a survey of experimental studies of jury voting games with information aggregation.

observed under majority rule.[8]

3 Crisis Bargaining Games

We model simple crisis bargaining situations using a sender-receiver signaling games, involving two players, 1 (sender, or first mover) and 2 (receiver, or second mover). A fair coin flip before the game starts determines whether 1 is either Strong or Weak, and this is private information to 1. Player 2 only knows that 1 is strong with probability 0.5. The game takes place in two stages. In the first stage, 1 makes a binary choice between the actions Escalate (In) and Concede (Out). If 1 chooses Out, the game ends with 1 receiving a payoff of $-a$, and 2 receiving a payoff of a, where $a > 0$ is called the *concession payoff*.

If 1 instead chooses In, the game moves to the next stage and it is 2's turn to choose between the actions Fight (In) and Concede (Out). If 2 chooses Out, then 2 loses the concession payoff of $-a$ and 1 gains a. If 2 chooses In, conflict ensues and payoffs depend on whether 1 is strong or weak. If 1 is strong, then 1 receives a payoff $a + s$ and player 2 receives a payoff of $-(a+r)$, where $r, s > 0$. If 1 is weak, then 1 receives a payoff of $-(a+s)$ and 2 receives a payoff of $a + r$. We call s the *sender risk* and r the *receiver risk*.

This game models a situation in which two parties, and informed sender and an uninformed responder, can choose - in sequence - between either accepting a certain small loss to the other party, or risking a larger loss (gain) if they are are weaker (stronger) than the other party. The motivating example is one where there is a crisis between two countries. One country (player 1) can threaten to escalate the crisis or suffer the a loss from conceding and letting the crisis be resolved in the second country's favor. If the crisis is escalated, the second country responds by either fighting or conceding.[9]

[8] Goeree and Yariv (2011) find a similar and even stronger effect of preplay communication if a richer communication protocol is used.

[9] There are many other applications. For example, a union that is privately informed of the costs to their members of striking and accepting an unattractive contract first decides whether to threaten a strike, and the employer must decide whether to call the bluff or back down upon being threatened. We call such games 'simplified poker', because, in the special case where $r = s$, it corresponds to a poker-like card game, where the first mover is randomly dealt either a high or low card after each player has put in the pot an ante equal to a. The game also corresponds to the "simple card game" in Myerson (1991) where first mover is dealt either a high or low card and can either bet an additional r (IN) or fold (OUT). If she bets, then the second mover can either meet the bet (IN) or fold. If both players bet, then the first (second) player wins the pot if the card is high (low). Simplified poker games have a storied history in the theory of games, with many different variations analyzed by Bellman and Blackwell (1949),Borel and Ville (1938), Morgenstern and von Neumann (1947), Kuhn (1950), and others.

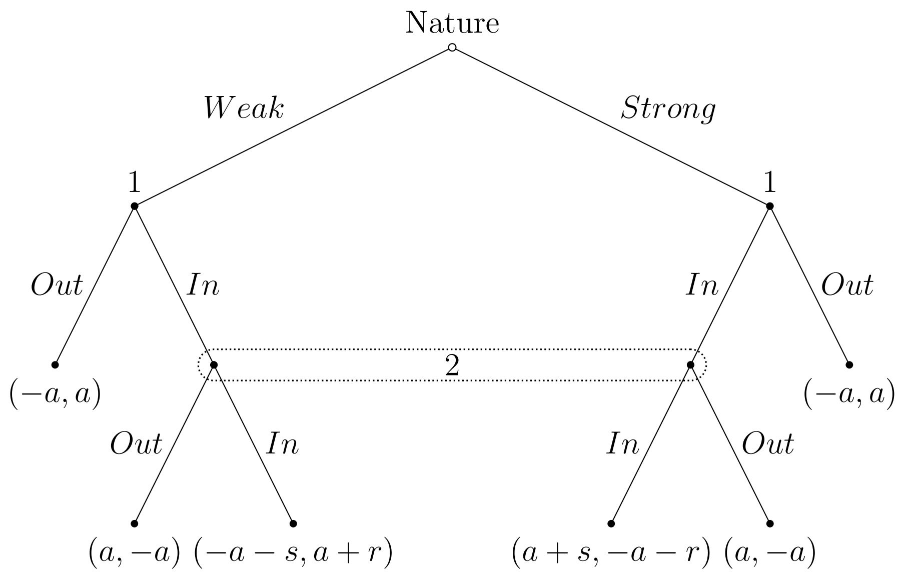


Figure 1: Game Tree of Binary Signaling Game.

3.1 Perfect Bayesian Equilibrium

In a crisis bargaining game there is a unique totally mixed Perfect Bayesian Equilibrium (PBE), which also corresponds to the unique PBE. The PBE of the crisis bargaining game consists of a 4-tuple, $(p_{1S}^{PBE}, p_{1W}^{PBE}, p_2^{PBE}, \mu^{PBE})$ where p_{1S}^{PBE} is the probability a strong player 1 chooses In, p_{1W}^{PBE} is the probability a weak player 1 chooses In, p_2^{PBE} is the probability 2 chooses In in response to In, and μ^{PBE} is 2's belief that 1 is strong, conditional on 1 choosing In, derived from Bayes' rule.

The strong player 1 has a dominant strategy to choose IN, so $p_{1S}^{PBE} = 1$.

If 1 is weak, equilibrium requires that they mix by choosing In with probability p_{1W}^{PBE} such that 2 is indifferent between responding In or Out; similarly, 2 must mix to make weak player 1 indifferent between In and Out. It is easy to see that the PBE is pinned down by three equations:

$$\begin{aligned}
p_2^{PBE}(-a-s) + (1-p_2^{PBE})a &= -a \\
\mu^{PBE}(-a-r) + (1-\mu^{PBE})(a+r) &= -a \\
\mu^{PBE} &= \frac{1}{1+p_{1W}^{PBE}}
\end{aligned}$$

and hence the PBE solution is:

$$
\begin{aligned}
p_{1S}^{PBE} &= 1 \\
p_{1W}^{PBE} &= \frac{r}{2a+r} \\
p_{2}^{PBE} &= \frac{2a}{2a+s} \\
\mu^{PBE} &= \frac{2a+r}{2a+2r}
\end{aligned}
$$

Notice that the equilibrium In probabilities for the two players move in opposite directions as the concession payoff a changes. As a increases, 2 chooses In more often, and 1 chooses In less often in equilibrium. Also note that the sender risk, s, affects only the equilibrium strategy of the receiver, and r affects only the equilibrium strategy of the sender.

3.2 Team equilibrium

The experimental design, hypotheses, and analysis of results are guided by the theory of team equilibrium in games (Kim et al. (2022)). In a team equilibrium, individual members of each team have rational expectations about the strategies of the other team, and share the same payoffs on average, but have unobserved i.i.d. payoff perturbations. Team decisions are made according to a voting rule and are the result of optimal voting decisions by each individual member of each team. In this paper, we specify the payoff disturbances as being distributed according to an extreme value distribution with precision λ, so it corresponds to the logit specification of team equilibrium.

We next describe the theory of team equilibrium in this section, specialized to our crisis bargaining games, where, at each information set, each team chooses a strategy either by majority rule voting or unanimity rule. Because of the voting rule and the payoff disturbances, the collective choice rule can result in either more or less bluffing compared to the PBE of the game, and either more or less aggressive responses to threats, depending on the exact payoff structure in the crisis bargaining game.

3.3 Team equilibrium in Crisis Bargaining Games

Here we define and characterize the team equilibrium for our family of crisis bargaining games as a function of the three payoff parameters, a, r, s, and the logit responsiveness parameter, λ, assuming equal-sized teams with an odd number, n, of members of each team.

A team equilibrium consists of a profile of behavioral strategies for each team, and a belief that the sender is strong, conditional on the sending choosing In. Team 1 (the sender) has two information sets and Team 2 (the receiver) has only one information set, so a team equilibrium strategy profile is denoted by a triple, (p_{1S}^{n*},p_{1W}^{n*},p_2^{n*}), where p_{1S}^{n*} be the equilibrium frequency with which team 1 chooses I (IN) when Strong, p_{1W}^{n*} be the equilibrium frequency with which team 1 chooses I (IN) when Weak, and p_2^{n*} is the equilibrium frequency with which team 2 chooses IN after team 1 chooses IN. The equilibrium belief that the sender is strong, conditional on the sender choosing In is denoted by μ^{n*}.

A team equilibrium is a fixed point mapping from the set of team mixed strategy profiles into itself, and any fixed point of this mapping is an equilibrium of the team game in the following way. Consider any profile of team (mixed) strategies and the corresponding beliefs of team 2 following an IN choice by team 1, where the beliefs are consistent with Bayes' rule. Any such profile implies expected payoffs for IN and OUT at each information set. Each member of a team whose turn it is to choose at that information set votes either IN or OUT. Because of the payoff disturbances of each voter, the strictly positive probability of each member of the team voting IN at that information set is given by the logit formula, applied using the expected payoffs of IN and OUT. The team decision probabilities then depend on how these votes are aggregated, which is specified by the collective choice rule (either majority rule or unanimity in our experiment). The resulting team decision probabilities define new expected payoffs, which in turn imply a new profile of team (mixed) strategies and beliefs. The profile is a team equilibrium if it is mapped into itself in this way. It is easy to show that a team equilibrium exists for any finite game. In crisis bargaining games, it also turns out that the team equilibrium (like the PBE) is always unique.

3.3.1 Games played by single member teams: $n = 1$

The case of single-member teams, corresponding to a unitary actor equilibrium, is especially simple and familiar because it reduces to the logit quantal response equilibrium (QRE) of the crisis bargaining game, and is characterized as follows. The behavioral strategy for each type of each player is given by the logit response to the expected payoff from the two actions. The expected payoff for Out is $-a$ for both types of senders and also for the receiver. Given an equilibrium strategy profile p^* and beliefs μ^*, the expected payoffs to Strong player 1, Weak player 1, and player 2 for choosing In are, respectively (dropping the n superscript):

$$U_{1S}(In) = p_2^*(a+s) + (1-p_2^*)a$$
$$U_{1W}(In) = p_2^*(-a-s) + (1-p_2^*)a$$
$$U_2(In) = \mu^*(-a-r) + (1-\mu^*)(a+r) = -a$$

Since p^* is a (logit) team equilibrium strategy profile, it must satisfy the logit response equations, which are given by:

$$p_{1S}^* = \frac{e^{\lambda[p_2^*(a+s)+(1-p_2^*)a]}}{e^{\lambda[p_2^*(a+s)+(1-p_2^*)a]} + e^{-\lambda a}}$$
$$p_{1W}^* = \frac{e^{\lambda[p_2^*(-a-s)+(1-p_2^*)a]}}{e^{\lambda[p_2^*(-a-s)+(1-p_2^*)a]} + e^{-\lambda a}}$$
$$p_2^* = \frac{e^{\lambda[\mu^*(-a-r)+(1-\mu^*)(a+r)]}}{e^{\lambda[\mu^*(-a-r)+(1-\mu^*)(a+r)]} + e^{-\lambda a}}$$

and the fourth equation characterizing the team equilibrium when $n = 1$ (QRE) is the Bayesian restriction on player 2's beliefs about player 1's type conditional on player 1 choosing In:

$$\mu^* = \frac{p_{1S}^*}{p_{1S}^* + p_{1W}^*}.$$

3.3.2 Games played by multi-member teams under majority rule

The case of multi-member teams requires additional notation for the collective choice rule. We denote by the triple, $(v_{1S}^{n*}, v_{1W}^{n*}, v_2^{n*})$ the vote probabilities for individual members of a strong sender team, a weak sender team, and the responder team. respectively. In a team equilibrium, these individual member vote probabilities follow logit best responses, just as in the QRE for the $n = 1$ case. That is:

$$v_{1S}^{n*} = \frac{e^{\lambda[p_2^{n*}(a+s)+(1-p_2^{n*})a]}}{e^{\lambda[p_2^{n*}(a+s)+(1-p_2^{n*})a]} + e^{-\lambda a}}$$
$$v_{1W}^{n*} = \frac{e^{\lambda[p_2^{n*}(-a-s)+(1-p_2^{n*})a]}}{e^{\lambda[p_2^{n*}(-a-s)+(1-p_2^{n*})a]} + e^{-\lambda a}}$$
$$v_2^{n*} = \frac{e^{\lambda[\mu^{n*}(-a-r)+(1-\mu^{n*})(a+r)]}}{e^{\lambda[\mu^{n*}(-a-r)+(1-\mu^{n*})(a+r)]} + e^{-\lambda a}}$$

In the case of $n = 1$, the individual member vote probabilities and the team majority rule decision probabilities coincide, but that is no longer the case when $n > 1$, where the majority decision probability of In is equal to the probability that more than $n/2$ individual voters vote for In. These probabilities, are given by standard binomial formulas derived from v_{1S}^{n*}, v_{1W}^{n*}, and v_2^{n*}:

$$
\begin{aligned}
p_{1S}^{n*} &= \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} (v_{1S}^{n*})^j (1 - v_{1S}^{n*})^{n-j} \\
p_{1W}^{n*} &= \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} (v_{1W}^{n*})^j (1 - v_{1W}^{n*})^{n-j} \\
p_{2}^{n*} &= \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} (v_{2}^{n*})^j (1 - v_{2}^{n*})^{n-j}.
\end{aligned}
$$

3.3.3 Games played by multi-member teams under unanimity rule

The unanimity rule we consider here specifies that the team decision is In unless every individual member of the team votes for Out. All of the analysis in the previous section continues to hold, with the exception of the last three equations, which become:

$$
\begin{aligned}
p_{1S}^{n*} &= \sum_{j=1}^{n} \binom{n}{j} (v_{1S}^{n*})^j (1 - v_{1S}^{n*})^{n-j} \\
p_{1W}^{n*} &= \sum_{j=1}^{n} \binom{n}{j} (v_{1W}^{n*})^j (1 - v_{1W}^{n*})^{n-j} \\
p_{2}^{n*} &= \sum_{j=1}^{n} \binom{n}{j} (v_{2}^{n*})^j (1 - v_{2}^{n*})^{n-j}.
\end{aligned}
$$

3.3.4 Perfect Bayesian Equilibrium as a Benchmark

A natural question to ask is whether, holding fixed the number of members on each team, the unique logit team equilibrium converges to the PBE in crisis bargaining games as the logit response parameter converges to ∞. From McKelvey and Palfrey (1998), convergence of QRE guarantees that this is true for the case of $n = 1$. Here we show that this convergence result also holds for both the majority and unanimity voting rules.[10]

[10] In fact, the convergence result holds for general threshold voting rules that require at least m out of n voters to vote for In in order for In to be the team decision, for $m = 1, 2, ..., n$. Moreover, the threshold does not have to be the same for both teams.

Proposition 1. *Fix n odd. For both the majority voting rule and unanimity voting rule, the team equilibrium in crisis bargaining games converges to the PBE as $\lambda \to \infty$. That is:*

$$\lim_{\lambda\to\infty}(p_{1S}^{n*}(\lambda), p_{1W}^{n*}(\lambda), p_2^{n*}(\lambda), \mu^{n*}(\lambda)) = (1, \frac{r}{2a+r}, \frac{2a}{2a+s}, \frac{2a+r}{2a+2r})$$

Proof: It is easy to see that $p_{1S}^{n*}(\lambda) \to 1$ since In is strictly dominant for strong player 1. It is also clear that if $p_{1W}^{n*}(\lambda) \to \frac{r}{2a+r}$ then $\mu^{n*}(\lambda) \to \frac{r}{2a+r}$. Hence, we only need to show that $(p_{1W}^{n*}(\lambda), p_2^{n*}(\lambda)) \to (\frac{r}{2a+r}, \frac{2a}{2a+s})$. Suppose to the contrary that $p_{1W}^{n*}(\lambda) \to p > \frac{r}{2a+r}$. Then $\mu^{n*}(\lambda) \to \mu < \frac{2a+r}{2a+2r}$ so In is strictly better than Out for player 2. Hence, $v_2^{n*}(\lambda) \to 1$, which in turn implies that $p_2^{n*}(\lambda) = \sum_{j=1}^{n} \binom{n}{j}(v_2^{n*}(\lambda))^j(1-v_2^{n*}(\lambda))^{n-j} \to 1$. But $p_2^{n*}(\lambda) \to 1$ implies that Out is a strict best response for weak player 1, so $v_{1W}^{n*}(\lambda) \to 0$, implying that $p_{1W}^{n*} = \sum_{j=1}^{n} \binom{n}{j}(v_{1W}^{n*})^j(1-v_{1W}^{n*})^{n-j} \to 0$, a contradiction. A similar logic reaches a contradiction, if we suppose that $p_{1W}^{n*}(\lambda) \to p < \frac{r}{2a+r}$ or if we suppose that $p_2^{n*}(\lambda) \to p \neq \frac{2a}{2a+s}$.

Given this convergence, the PBE of the game is a natural benchmark for comparison of team equilibrium. and suggests the hypothesis that that multi-member team behavior will be closer than individual behavior to PBE predictions.[11] However, since there is no general monotonicity property of convergence to PBE in these games, in principle it could be possible for small or intermediate range of λ that is often found in experiments, it is possible that the team equilibrium of a game drifts is further from PBE with multi-member teams.

4 Experimental Design and Team Equilibrium

4.1 Games and Treatments

We have a 3×4 treatment design, with three different team treatments and four sets of payoffs in the crisis bargaining game. Both the number of team members and voting rule employed by a team are varied across team treatments. In the 'Individual' treatment, individual subjects competed against with one another in the 1v1 version of the game. In the 'Majority' treatment, teams of 5 subjects using majority voting to select actions competed with one another. Finally, teams of 5 using a unanimity voting rule with a default action of 'IN' competed in the 'Unanimity' treatment.

Depending on the payoff parameters, equilibrium In probabilities can either be above or below $\frac{1}{2}$ for weak first movers and second mover respectively. The four payoff treatments

[11] Such a hypothesis is also indicated based on evidence of team behavior across a wide range of other types of games, as documented in a survey by Charness and Sutter (2012).

Table 1: Experimental Game Payoff Parameters and PBE mixed strategies

	concession payoff (a)	sender risk (s)	receiver risk (r)	p_{1W}^{PBE}	p_2^{PBE}
Game 1	10	5	5	$\frac{1}{5}$	$\frac{4}{5}$
Game 2	4	16	4	$\frac{1}{3}$	$\frac{1}{3}$
Game 3	3	15	15	$\frac{5}{7}$	$\frac{2}{7}$
Game 4	4	4	16	$\frac{2}{3}$	$\frac{2}{3}$

were chosen so that each possible arrangement is represented. The four sets of payoffs, along with their equilibria, are presented in Table 1. Game 1 involves player 1 choosing OUT a majority of the time and player 2 choosing IN a majority of the time, game 2 both below $\frac{1}{2}$, game 3 the reverse of game 1, and game 4 both above $\frac{1}{2}$.

4.2 Computations of Team Equilibrium

In this subsection, for illustration we compute team equilibrium for Game 1 for the three team treatments and two roles, and provide an explanation of the comparative statics of equilibrium for this game as an example. As shown in Proposition 1, team equilibrium team frequencies of IN always converge to PBE frequencies as $\frac{1}{\lambda}$, the variance of team member payoff disturbances, goes to 0. Here the PBE mixing probabilities are $p_{1W}^{PBE} = 1/5$, $p_2^{PBE} = 4/5$. This example illustrates how non-monotonic convergence to the PBE can happen. In this game, for low values of λ the logit team equilibrium choice probabilities actually *move further away from PBE* as λ increases larger. One also sees that the team choice rule (majority or unanimity) can influence logit team equilibrium by biasing team choices toward one of the actions.

The left panel of Figure 2 shows how the Game 1 team equilibrium IN frequency for weak first movers, p_{1W}^* varies with λ, for each of the three team treatments. The right panel shows the same for second movers, p_2^*. Each curve traces out the logit team equilibrium for values of λ between 0 and 2, on the x-axis.[12] We will first discuss the comparative statics of the team equilibrium model with respect to λ for majority rule teams and individuals, then the equilibrium effects of the majority rule treatment, and finally discuss the unanimity treatment.

[12]Appendix 2 contains analogous figures for Games 2-4.

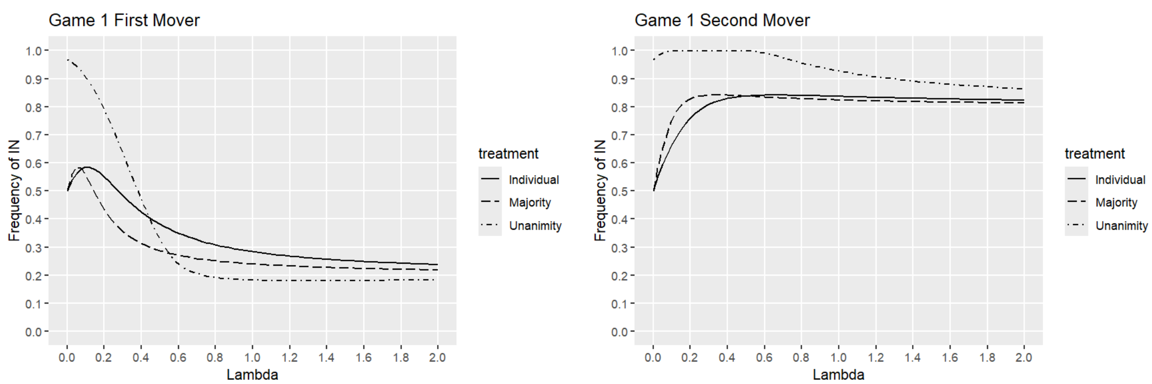


Figure 2: Game 1 Team Equilibrium

The figure shows how team equilibrium always converges to the game 1 PBE of 1/5 for weak first movers and 4/5 for second movers as λ goes to infinity, irrespective of the choice rule. At $\lambda = 0$, team members are completely unresponsive to payoffs and mix uniformly in their voting behavior between IN and OUT, resulting in a team frequencies of 1/2 for majority rule and individuals.[13]

The non-monotonicity of convergence to PBE for Weak first movers arises in Game 1 because, for values of λ close to 0, the expected payoff of IN is approximately $\frac{1}{2}a+\frac{1}{2}(-a-s) = -\frac{1}{2}s$, which is strictly greater than the OUT payoff of $-a$ since $s = 5$ and $a = 10$. Team members become more responsive to expected payoff differences as λ increases, and so in this game, they begin to vote for IN at higher rates as λ increases from 0. As λ increases, the second mover behavior changes as well, increasing from $\frac{1}{2}$ until crossing the PBE level of 0.8. At that point, the expected payoffs of IN and OUT become equal for Weak first movers by the definition of equilibrium, and so p^*_{1W} exactly equals $\frac{1}{2}$.

Understanding the comparative statics of p^*_2 with respect to λ is more subtle, as one needs to consider the effects on 2's incentives resulting from changes in a 50/50 *mixture* of Strong and Weak type first movers choosing IN. The more Weak types go IN relative to Strong types, the greater the incentive for second movers to also go IN. Because strong and weak first mover team members behave identically at $\lambda = 0$, a Bayesian second mover does not gain any information from the fact that the first mover team chose IN. The probability of strength conditional on choosing IN is the same as the prior. Consequently, the second mover

[13]Not displayed in the graph is the team equilibrium IN frequency for Strong first movers, which also starts out at 1/2 for majority rule and individuals, and very quickly converges to 1. (It starts out at $1 - (1/2)^5 = 31/32$ with unanimity rule.)

expected payoff from going IN against a first mover with $\lambda = 0$ is $\frac{1}{2}(a + r) + \frac{1}{2}(-a - r) = 0$, which is greater than the payoff of $-a$ from choosing OUT. For infinitesimal increases in λ we can ignore the effect of changes in first mover team behavior on expected payoffs, and conclude that second mover team members become more likely to vote IN.

Note that in the majority rule and individual treatments in game 1, Weak first movers and second movers both converge to the PBE from above. This is due to the fact that for these choice rules, teams are more likely, in any team equilibrium, to choose the action with the higher expected payoff. Whenever a team equilibrium frequency crosses the PBE, the opponent team equilibrium frequency must cross $\frac{1}{2}$ at that value of λ, because the PBE level equalizes the opponent's expected payoffs. Since in game 1 the second mover PBE is above $\frac{1}{2}$, it must be the case that for large values of λ, IN has a higher expected payoff, and so there must be too many Weak first movers choosing IN relative to equilibrium. Since the first mover PBE is below $\frac{1}{2}$ in game 1, it must be the case that second mover teams choose IN too often in team equilibrium relative to the PBE. Therefore, for large λ, we must have that both roles choose IN too often.

In the unanimity treatment, $\lambda = 0$ second mover teams start out above the PBE because the voting rule biases team behavior toward IN. In particular, when $\lambda = 0$ all team members mix uniformly between voting for IN and OUT resulting in a team frequency of IN of 31/32, which is greater than the second mover PBE level for all of our games. Therefore OUT is the best response for Weak first movers, and the probability any team member votes for IN must decrease as λ increases. As mentioned above, second mover team members gain no information from the fact that $\lambda = 0$ first movers choose IN, and so second mover team equilibrium IN frequencies increase in λ at low values of λ. As can be seen from the right panel of Figure 2, second mover teams choose IN with near certainty at lower values of λ, and do not begin appreciably decreasing towards the PBE until first movers are already very close to 1/5.

Under unanimity rule at large values of λ, we may need team members to vote for IN with very low probabilities in order for the team frequency of IN to approach the PBE, even when that PBE is above $\frac{1}{2}$. Since team members are more likely to vote for the higher expected payoff action, OUT must have a higher expected payoff than IN for large values of λ in the unanimity treatment for all of our games. This is why Weak first mover teams using unanimity rule must converge to the PBE from below, while second mover teams using unanimity rule must converge to the PBE from above.

Finally we explain the separation between equilibrium majority rule team behavior and individual behavior. In the team equilibrium model, voters are assumed to vote sincerely for the team action that they prefer, given their individual, random expected payoff disturbance, and these disturbances are assumed to have the same distribution regardless of team size and the choice rule employed. As a result, for a given value of λ and given expected payoffs for choosing IN and OUT, team members vote for IN with the same frequency that individual decision makers unilaterally choose IN. The majority voting rule then 'magnifies' these individual choice probabilities in a Condorcet jury type effect. If voters vote for IN with probability less than (greater than) $\frac{1}{2}$, IN wins the election with probability closer to 0 (1). We call this effect the 'reinforcement effect' of majority rule voting.

In Figure 2, near $\lambda = 0$ the dashed line representing the majority rule team equilibrium increases faster than the solid line representing the individual team equilibrium, due to this reinforcement effect. In addition to this effect, there is an 'equilibrium effect' created by the influence of majority rule voting on the opponent team behavior. Since second mover majority rule teams reach the PBE level of IN frequencies at lower values of λ than individuals, the majority rule Weak first mover IN frequency must begin to decrease at lower values of λ than do individuals. This means that majority rule teams vote for IN more frequently than individuals go IN for some values of λ, and less frequently for higher values of λ. A similar effect can be seen in the team equilibrium of the second movers, however the separation between treatments is less pronounced for second movers than for first movers for this particular set of payoffs.

For sufficiently large values of λ, majority rule teams are closer to PBE than individuals. In this way our theory captures the typical result of the prior literature that teams are closer to equilibrium than individual decision makers. For these crisis bargaining games, this result only holds if subjects have sufficiently small payoff disturbances and use a neutral voting rule such as majority rule voting. With larger payoff disturbances, in other words, with more heterogeneity between team members, or non-neutral voting rules, team equilibrium effects may drive teams either further or closer to equilibrium depending on payoff parameters. These observations lead naturally to the research questions we present in the next section.

4.3 Research Questions

Since PBE serves as a benchmark model for the games used in this paper, the following question naturally arises: can PBE explain behavior in our experiment? To empirically examine this question, we can analyze the choice frequencies of IN across all treatments and the individual vote frequencies in the Majority and Unanimity treatments. This analysis would be the first step in determining whether the unitary actor approach in game theory is adequate.

Question 1: Does PBE adequately explain behavior in all treatments?

The stylized finding in the literature is that teams are closer to Nash equilibrium than individuals. Our next question is whether this finding still holds true in our experiments. Given that there is a unique PBE, it is possible, as shown above, that teams deviate even further from PBE than individuals under the framework of team equilibrium. This leads us to the following question:

Question 2: Are teams always closer to PBE than individuals?

We next turn our attention to the impact of collective choice rules on behavior. In previous experiments, the most commonly used collective choice was a consensus rule, where team members were required to reach a single decision through deliberations, either face-to-face communication or chat. Given the monotonous approach taken in the literature, comparing different collective choice rules (Majority vs. Unanimity) in strategic interactions is a novel feature of our experiment. Finding significant differences in behavior under the two collective choice rules highlights the necessity of moving beyond the unitary actor approach.

Question 3: Do collective choice rules matter for team behavior?

The possibility that teams can deviate further from PBE than individuals raises the question of how we define more rational behavior. A mere distance from PBE does not necessarily indicate superior rationality. To address this concern, we adopt a new approach that focuses on responsiveness to differences in expected payoffs. Specifically, following team equilibrium, all weak types' expected utility either monotonically increases or decreases with their own probability of choosing IN, assuming the other player's deviation from equilibrium remains constant. By examining whether teams or individuals are more responsive to differences in expected payoffs when choosing IN or OUT, we can better assess rationality. This approach enables us to answer the following question:

Question 4: Are teams more rational than individuals?

We have discussed the challenges of defining and measuring more rational behavior between teams and individuals. Our core concept of rationality, which responds better to expected payoff differences, is well-reflected in the framework of team equilibrium. The superior responsiveness of teams to expected payoff differences translates into common knowledge, which in turn creates an equilibrium effect influencing each team member's voting probabilities. Given the complex feedback loop between beliefs and actions, our final research question focuses on the explanatory power of team equilibrium. Specifically, we will investigate how team equilibrium captures differences in game payoffs and collective choice procedures:

Question 5: Does team equilibrium adequately explain behavior in all treatments?

4.4 Procedures

We conducted a total of 19 sessions with subjects recruited either from the Experimental Social Science Laboratory (ESSL) at UC Irvine, or from UC Santa Barbara. In each session, one team treatment was implemented. The individual treatment was conducted in 8 sessions, the majority treatment in 6 and the unanimity rule treatment in 5.

In each session subjects participated in 10 rounds of each of the 4 games for a total of 40 rounds. In half of the sessions, the order of games was 1234, and in the other half of sessions, the reverse order, 4321, was used. Subjects were randomly re-matched with new team members and a new opponent team between every round. Subject roles and the team treatment was held fixed for all rounds in a session. The subject interface and software for the experiment was programmed in OTree.

At the beginning of each session the experimenter read the instructions aloud, including specific payoff information for the first game, and displayed examples of the subject interface on a projector in front of the room.[14] After these instructions were finished, a short comprehension quiz was completed by the subjects. Subjects were required to provide correct

[14]A sample of the instructions and the a sample Powerpoint slideshow are available in the supplemental online appendix.

answers to all questions before moving on to the first round of the experiment. After the 10 rounds of the first game were finished, the experimenter announced the new payoffs for the second game. Subjects then participated in 10 rounds of the second game, and so forth until all 40 rounds of the experiment were completed.

In each round of the experiment, the game was conducted sequentially as illustrated in Figure 1. First movers were initially informed of the result of a virtual coin flip, which determined whether the first mover was strong (Heads) or weak (Tails).

In the 1×1 session where each team was composed of a single individual, first movers were then prompted to choose an action, either IN or OUT. Second movers then observed their paired first mover's action choice, but not the result of the coin flip. If the first mover chose IN then second movers were prompted to make a choice. If the first mover chose OUT, the game ended without the second mover making a choice. After all decisions were made, feedback about the outcome was given to all subjects and second movers learned the state of the world.

In the 5×5 session, first movers were then prompted to *vote* for an action, either IN or OUT, with the first mover team's decision decided by the voting rule, either majority or unanimity, depending on the session. Second movers then observed their paired first mover team's decision, but not the result of the coin flip. If the first mover team chose IN then second movers were prompted to vote for either IN or OUT, with the second mover team's decision decided by the voting rule, either majority or unanimity, depending on the session. If the first mover team chose OUT, the game ended without the second movers making a choice. After all decisions were made, feedback about the outcome was given to all subjects. Second movers learned the state of the world, and in team treatments subjects were told the vote totals for both teams.

After the conclusion of all 40 rounds, one round from each game (total of 4 rounds) was randomly chosen for each subject to determine the payments. Sessions lasted on average 90 minutes, including instructional time. Subject earnings averaged \$32.1, which included a fixed payment of \$7 for showing up on time and a completion payment of \$5 for completing all rounds of the experiment. Subjects were paid for their decisions in an artificial currency, points, where each point had a value of \$0.20.[15]

[15] When the initial $1-1$ sessions were conducted, in-person experiments were not feasible due to the pandemic, so these sessions were conducted online through Zoom video conferencing. Online sessions are clearly identified in Table 4 in Appendix 1. In these sessions, occasionally a subject would become disconnected

5 Results

Choosing IN is a dominant strategy for strong first movers, and our first mover subjects in all treatments nearly always choose IN. All strong first mover teams in the Majority and Unanimity treatments choose IN, and IN is chosen more than 96.7% of the time in the Individual treatment. Therefore, our analysis of results in this section uses only the choice data from weak first movers and second movers.

5.1 Does PBE Explain Behavior?

Our first research question is whether PBE can effectively explain our data. Figure 3 compares the IN team choice frequency predicted by PBE (on the x-axis) with the observed IN team choice frequencies (on the y-axis) across all games and treatments.[16] Each point represents one game and team/choice rule treatment for players of one role, resulting in 24 points. When points lie on the dashed 45-degree line, the observed team choice frequency of IN matches the PBE frequency. Points that are far from the 45-degree line correspond to those treatments for which behavior deviates from PBE.

In general, there is a positive but weak relationship between PBE and observed frequencies of IN. The line of best fit, estimated using a linear regression and shown as a dotted line in the figure, has an intercept of 0.36 and a slope of 0.36, which is not statistically significant at the 5% level, with an R-squared of 0.12. Overall, we do not find evidence that PBE provides an informative explanation of our data.[17]

The three points corresponding to a given game and player role lie on a vertical line in Figure 3, as for each game the PBE choice frequency is invariant to the team size and

during the experiment, so it was necessary to address this issue by substituting a 'robot' stand-in player to replace a dropout player. If a player became disconnected during the session, the session was briefly paused to allow the experimenter to make a public announcement informing all remaining subjects. A robot player then took the place of the dropout, and chose IN with 50% probability and OUT with 50% probability at every opportunity, for the remainder of the session. Subjects were subsequently advised in any future round when they were paired with the robot, via a private announcement. It was announced publicly that rounds played against the robot player would not be selected for subjects' payoffs. The data from any such unincentivized games were discarded. In session 10 (the only online 5×5 session), a subject disconnection caused the experimental software to crash immediately following Round 20, so that session did not include any data from two of the games. See Table 4 in Appendix 1.

[16] In the Individual treatment, it refers to the choice frequency of IN.

[17] There is a slightly stronger relationship for second movers than for first movers, when the linear regression is estimated for only second movers, the intercept is 0.30 and slope is 0.57 with an R squared of 0.26, and when it is estimated for first movers alone, the intercept is 0.43 and slope is 0.12. However the difference is not statistically significant.

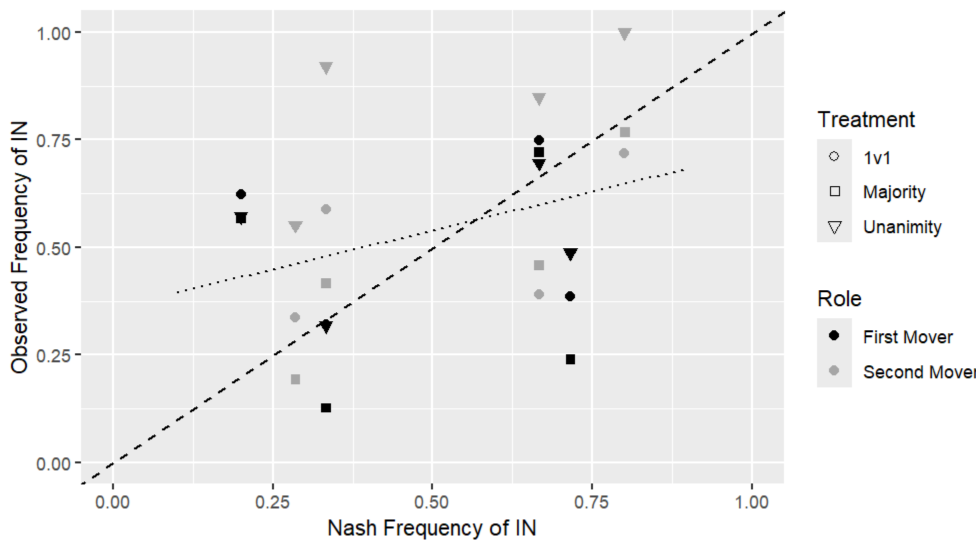


Figure 3: PBE and Observed Team Frequency of IN

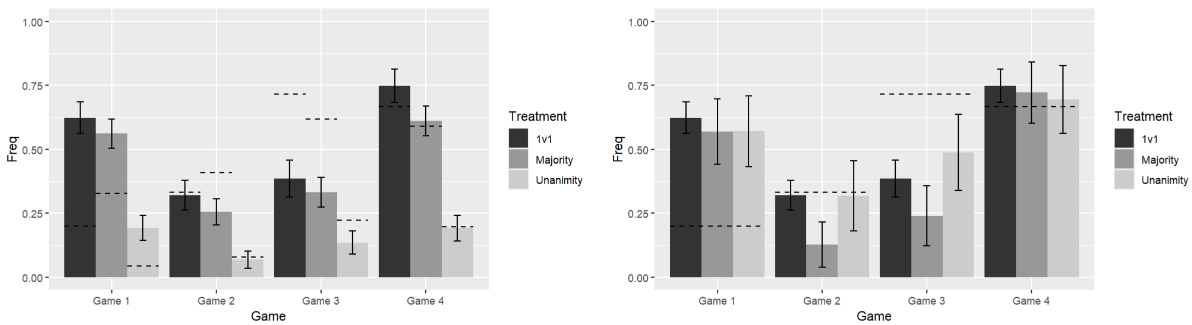
employed voting rule. This is due to the fact that team choice frequencies must make opponent team members indifferent between voting for IN and OUT. If team members' votes are sometimes pivotal, as in the symmetric mixed equilibrium we consider, this means that they must be indifferent between their team choosing IN and OUT. In equilibrium, team members must therefore adapt their voting probabilities to their team's voting rule in such a way that the team frequencies remain the same, i.e. team frequencies are fixed by payoffs, not choice rule. The symmetric PBE can therefore never explain differences in behavior between teams and individuals, or between teams using different choice rules. The team equilibrium theory, in contrast, allows team choice frequencies to vary with choice rule.

As can be seen from the placement of these points on the y-axis of the figure, for many of our games behavior varies widely between choice rule treatments. It is this variation that is the subject of the prior experimental literature on games played by teams. In the remainder of this section, we explore in greater depth the extent to which teams depart from PBE behavior in these crisis bargaining games, what the explanation for any treatment effects might be, and whether team equilibrium can account for the observed departures from PBE.

5.2 Are Teams Closer to PBE?

Given the poor explanatory power of PBE predictions for these bargaining games, our next question is whether teams tend to be closer to PBE than individuals. We first look at the behaviors of the first movers. The observed frequency of votes for IN, and team choices for

IN, are depicted in Figure 4. In the left panel, the vote frequencies of IN for all treatments and all games are shown. The dashed lines projected over the three bars for each game represent the PBE voting probabilities for each of the voting rule treatments.[18] In the right panel, the team choice frequencies of IN for all treatments and all games are presented.



(a) Weak First Mover Votes (b) Weak First Mover Team Decisions

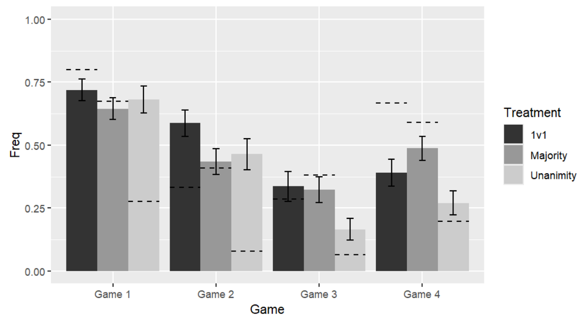
Figure 4: First Mover

As shown in both panels of Figure 4, there is no clear evidence that behavior in the two treatments is closer to the PBE predictions in terms of vote probabilities and team choice frequencies. In the left panel, while the choice frequencies of IN in the Individual treatments significantly differ from the PBE predictions in two out of four games at the 1% level, the same deviations from the PBE predictions in the Majority and Unanimity treatments are significant in three and two games, respectively, at the 1% level.[19] A similar pattern also applies to the team choice frequencies in the right panel.

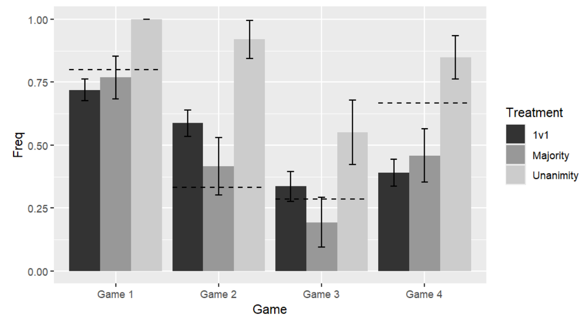
Figure 5 shows the voting frequencies and team decisions for the second movers across all treatments. Again, we do not find clear evidence that teams are closer to PBE. The choice frequencies of IN in the Individual treatment are significantly different from the PBE at the 1% level in all games except game 3. In the left panel, while the vote frequencies of IN in the Majority treatment significantly deviate from the PBE only in game 4, the vote frequencies of IN in the Unanimity treatment are significantly different from the PBE in all games. The same qualitative patterns persist in the right panel for the team choice frequencies of IN for both team treatments.

[18]In the Majority and Unanimity treatments, the PBE vote probabilities indicate the frequencies with which team members vote for IN, ensuring that the team's overall choice frequencies of IN align with the PBE of the original two-player game.

[19]Unless otherwise stated, the statistical significance of deviations from the PBE is assessed using Binomial test.



(a) Second Mover Votes



(b) Second Mover Team Decisions

Figure 5: Second Mover

Notably, numerous qualitative violations occur, where the observed frequencies do not align with the comparative statics predicted by PBE. Specifically, observed vote frequencies exceed the PBE in 4 out of 8, 3 out of 8, and 5 out of 8 cases in the Individual, Majority, and Unanimity treatments, respectively, with similar patterns evident in team choice frequencies. This suggests that observed behavior neither systematically overshoots nor undershoots the PBE IN frequencies, and different choice rules tend to lead to specific types of violations.

5.3 Do Collective Choice Rules Matter for Behavior?

Next, we examine the impact of collective choice rules on behavior. Most previous experiments have employed a consensus rule, requiring team members to reach a single decision through face-to-face communication or electronic chat. However, the effects of different collective choice rules on team decisions in strategic interactions remain underexplored. Thus, this paper's novel contribution lies in comparing majority and unanimity voting rules in signaling games.

Different collective choice rules significantly impact the team choice frequencies of IN, varying by role in the games. In the right panel of Figure 4, the frequencies of IN choices in games 2 and 3 are notably higher in the Unanimity treatment compared to the Majority treatment (p-values = 0.027 and 0.017, respectively), whereas no significant differences are observed in games 1 and 4 (p-value > 0.827).[20] As illustrated in the right panel of Figure 5, these differences become more pronounced, with the frequencies of IN choices as a second mover being consistently and significantly higher in the Unanimity treatment compared to

[20]Unless otherwise stated, the statistical significance of the difference between the treatments is assessed using a two-sided Fisher's exact test.

the Majority treatment (p-values < 0.01).

For the vote frequencies of IN in both treatments, the differences are more pronounced for first movers. In the left panel of Figure 4, the vote frequencies of IN for first movers in the Unanimity treatment are consistently lower than those in the Majority treatment, with all differences being statistically significant (p-values < 0.01). However, as shown in the right panel of Figure 5, the vote frequencies of IN in the Unanimity treatment increase when participants play as second movers rather than first movers. Consequently, the differences in the vote frequencies of IN between the Majority and Unanimity treatments are significantly different in games 3 and 4 (p-values < 0.01).

Although significant differences in team choice and vote frequency of IN are observed between the two treatments for most games, these differences are not well explained by PBE. Specifically, the vote frequencies of IN for second movers in the Unanimity treatment consistently exceed the levels predicted by PBE, while for first movers, they fall well below the PBE in 3 out of 4 games. This discrepancy results in significantly lower vote frequencies of IN for first movers in the Unanimity treatment compared to the Majority treatment. The asymmetric effects of collective choice rules on behavior raise questions about how best responses of teams in each role vary across treatments, in response to expected payoffs determined by teams in the opposite role, ultimately leading to convincing team equilibrium behavior. Therefore, the next two subsections will demonstrate: (1) the systematic differences between teams and individuals in their responsiveness to variations in expected payoffs, and (2) how this differing responsiveness translates into equilibrium behavior within the framework of team equilibrium.

5.4 Are Teams More Rational Than Individuals?

In our games, all second mover teams and weak first mover teams best respond by choosing OUT (IN) with probability 1 when their opponent chooses IN (OUT) too frequently relative to equilibrium. Only in the knife-edge case, when opponents choose IN with the equilibrium mixing probability, are teams indifferent between IN and OUT. Holding opponent deviation from equilibrium constant, the team's expected utility is either monotonically decreasing or increasing in their own probability of choosing IN. Intuitively, we can test the idea that teams are more rational than individuals by examining whether majority rule teams have more extreme team choice frequencies, holding opponent deviations from the equilibrium constant.

We implement this test by computing the observed expected payoff for choosing IN and OUT for each treatment and game. We then estimate a logit model with expected payoff difference between IN and OUT as the explanatory variable and team choice of IN as dependant variable. The larger the estimated coefficient on expected payoff difference in the regression, the better teams are at responding to their opponents, or put another way, the more sensitive they are to their opponents' strategy.

In Table 2, estimates of logit regressions are reported. Each observation is a team choice, for first movers after TAILs, for second movers after the first mover it is paired with chooses IN. In column 1 are estimates from a simple regression of choice of IN on expected payoff difference between IN and OUT, not controlling for role or choice rule treatment. The positive sign of the constant indicates that, when IN and OUT yield equal expected payoffs, teams are predicted to choose IN at a slightly higher rate than OUT. The positive coefficient on expected payoff difference, labelled 'Pay Diff' indicates that teams are more likely to choose IN the higher the expected payoff for IN relative to OUT.

The second column contains estimates for a regression that includes controls for team role. There is no statistically significant difference between first movers and second movers in their bias toward IN or OUT, or in their sensitivity to expected payoffs. Finally, the third column regression control for treatment. Majority rule teams are significantly more likely to choose OUT than individuals when payoff differences are close to 0, and are significantly more sensitive to payoff differences than individuals. Unanimity teams are more likely to choose IN, the default action, when payoff differences are close to 0, as expected. Interestingly, unanimity rule teams are also more sensitive to payoff differences than individuals.

In Figure 6, the fit of the estimated logistic regressions for majority rule voting and individual decision-making are shown. Each dot in the figure represents a different game and role for the Individual treatment, and each X represents the same for the Majority treatment. On the x-axis is the difference in expected payoffs between the team choosing IN and the team choosing OUT. On the y-axis is the observed frequency with which teams in the given treatment chose IN.

If teams were behaving according to PBE, all dots would be on the vertical line at 0 on the x-axis, meaning that all teams were indifferent between choosing IN and OUT. If teams were best responding, the dots would all be at 1 at the top of the graph when the expected

Table 2: Team Choice Logit Regressions

	Dependent variable:		
	Team Choice of In		
	(1)	(2)	(3)
Constant	0.156***	0.143***	0.060
	(0.036)	(0.049)	(0.043)
Majority			−0.309***
			(0.104)
Unanimity			1.439***
			(0.159)
First Mover		0.0005	
		(0.076)	
Pay Diff	0.134***	0.146***	0.141***
	(0.009)	(0.012)	(0.011)
Majority × Pay Diff			0.064**
			(0.029)
Unanimity × Pay Diff			0.070**
			(0.029)
First Mover × Pay Diff		−0.027	
		(0.019)	
			Observations
Observations	3,285	3,285	3,285
Log Likelihood	−2,139.164	−2,138.076	−2,070.334
Akaike Inf. Crit.	4,282.328	4,284.151	4,152.668
Note:			*p<0.1; **p<0.05; ***p<0.01

payoff difference is positive, and at 0 when the expected payoff difference is negative. Because teams are imperfect in their responses to their opponents strategies, we instead see an upward sloping relationship between payoffs and decision frequencies.

The solid line shows the predicted team frequency of IN for every payoff difference from the logistic regression on the Individual treatment data, also called the estimated response

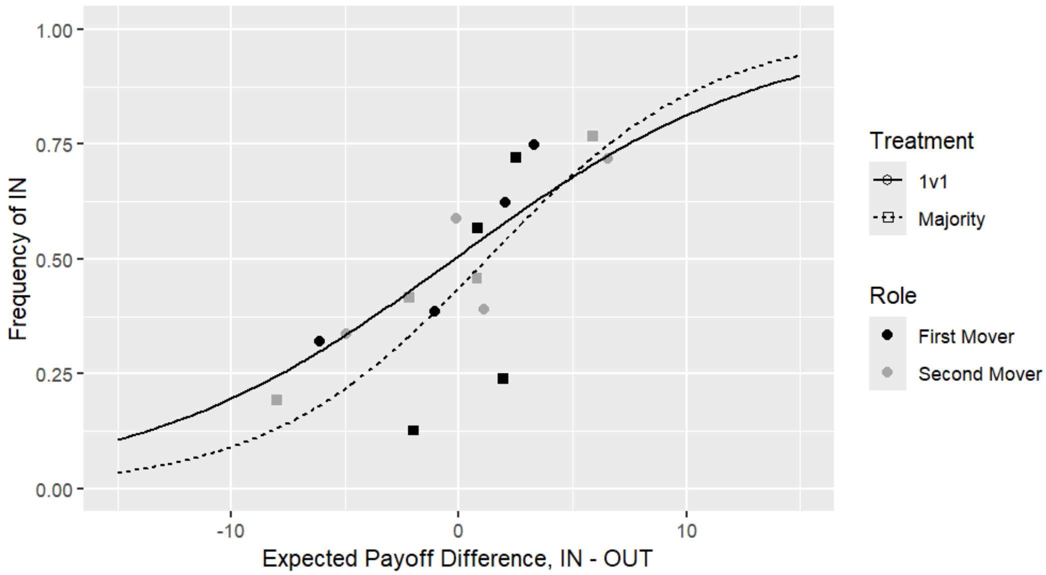


Figure 6: Majority Voting Logistic Regression

function for individuals, and the dashed line shows the estimated response function for majority rule voting teams. The Majority treatment teams are slightly more likely to choose OUT than Individuals are over most of the range of observed expected payoff differences, but the slope in their response function is also steeper. This is mostly caused by teams in some treatments voting for OUT at higher rates when OUT is the best response.

The same comparison between estimated response functions for unanimity teams and individuals is shown in Figure 7. Here, the in-built bias in the unanimity voting rule for IN is well expressed in a very high probability of teams choosing IN at indifference. Again, the team response function is steeper than the individual response function. In this case, unanimity teams are unsurprisingly very good at choosing IN when IN is the best response, which happens for second movers in some treatments in which too many weak first mover teams go IN, again due to the bias in the voting rule.

These estimates give some support for the common finding, and potential explanation for closer team behavior to PBE, in the prior literature that teams are better at maximizing their payoffs than individual decision makers. Importantly, we find evidence for this treatment effect even when team members are not able to openly communicate with each other and only influence team behavior through binary votes. While many previous studies have argued that teams improve decision-making by spreading knowledge of solutions to strategic problems with a ‘eureka’ like key idea, our results show that merely by aggregating a large number

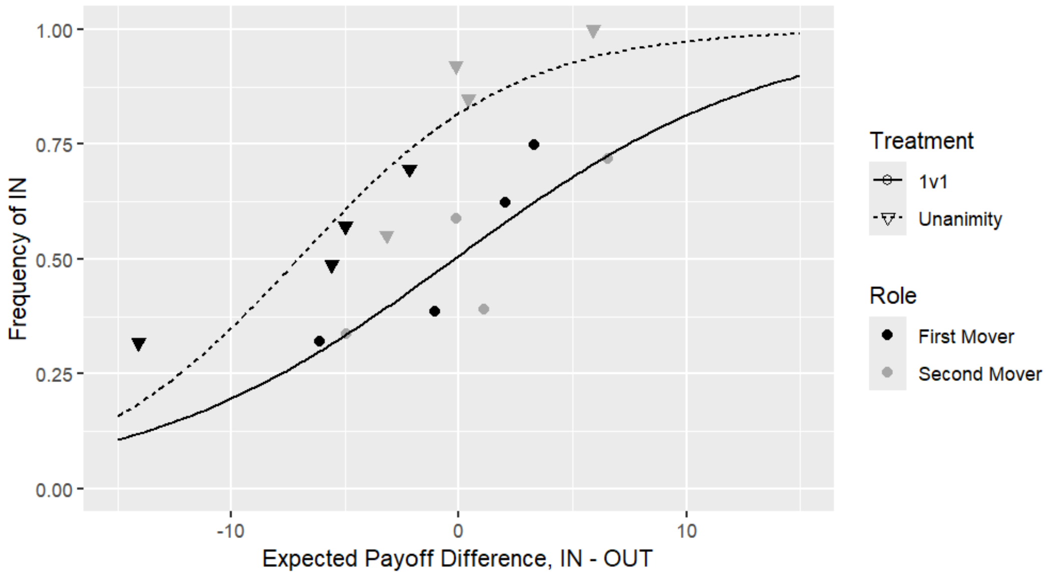


Figure 7: Unanimity Voting Logistic Regression

of opinions through a more low information mechanism such as voting can result in better collective decision-making.

5.5 Does Team Equilibrium Explain Behavior?

While PBE largely fails to organize the observed behavior in the crisis bargaining game, including the relationship between IN frequencies and payoff parameters, team equilibrium may offer a superior fit and explanation for the observed voting treatment effects. Team equilibrium makes the assumption that all team members' estimated expected utilities for team actions are random disturbances of the true expected utility given the behavior of the other team, but it is silent on the choice of distribution of these disturbances. In our main specification, we assume that all subjects in all games and team treatments are subject to the same distribution of payoff disturbances, namely mean zero type 1 extreme value disturbances yielding logit choice probabilities, all having the same unknown variance. Having assumed this distribution, we use standard maximum likelihood estimation methods to estimate the common unknown variance.

By including just a single free parameter to fit all of our data, we place the most stringent constraints on the team equilibrium model. This single parameter must provide a unified explanation for both the observed differences in behavior between games, and the observed differences between team treatments. In other words, to the extent that our model fits our observations and improves upon the PBE baseline, we argue that both payoff and team choice rule treatment effects ultimately issue from the same source of heterogeneity in individual preferences, beliefs or judgements.

We estimate the logit team equilibrium payoff disturbance parameter using maximum likelihood estimation using the weak player 1 data, and the player 2 data. Strong player 1 PBE strategies which choose IN with certainty are excluded. Although OUT is a strictly dominated action for player 1, it is occasionally (rarely) chosen in our data, so the log likelihood of our data under the PBE model would minus infinity if the strong player 1 data were included. Our focus is on the comparison of team equilibrium directly to the PBE baseline, so excluding strong player 1 data from the log-likelihood facilitates this direct comparison via fitted log-likelihoods.[21]

Team equilibrium makes predictions about both individual voting decision frequencies and team choice frequencies. In principle, observations of votes or team choices could be used to estimate team equilibrium model parameters. We choose to use votes for estimation because, assuming that team member votes are independent (a reasonable assumption in our setting with no communication and team rematching after every round), voting behavior gives us strictly more information than team choices as team choices are deterministic functions of team member votes.

The estimated team equilibrium logit parameter is $\hat{\lambda} = 0.1893$, equivalent to a payoff disturbance variance of 5.28. The minimized log-likelihood value is -4357.2, while the log-likelihood under the PBE is -4817.8. The log-likelihood ratio test yields a test statistic value of 921.3, which allows us to reject the hypothesis of PBE behavior with a very high degree of certainty.

Table 3: Model Estimates

	PBE	PBE+RA	TE	TE + RA	RG	PF
λ	(∞)	(∞)	0.189	0.670	(0)	-
ρ	(0)	-0.217	(0)	0.485	-	-
log-like	-4817.8	-4790.6	-4357.2	-4272.9	-4770.2	-4163.1
N	6882	6882	6882	6882	6882	6882

[21]Excluding these cases has essentially no effect on the estimates of the Team Equilibrium model.

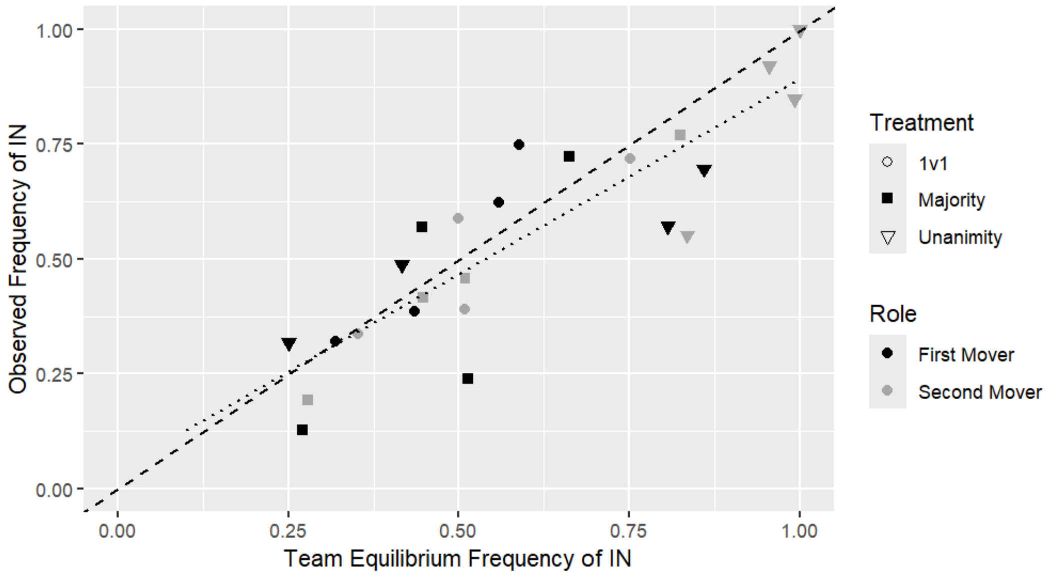


Figure 8: Team Equilibrium Fit

Figure 8 plots the observed team decision frequencies of IN against the frequencies of IN from the fitted team equilibrium model for each team treatment and participant role. Comparison to Figure 3 offers an additional check of the team equilibrium model performance relative to PBE. By introducing only a single single parameter for the team equilibrium model, the points more nearly lie along the 45 degree line, the intercept of the OLS regression line is 0.04 and the slope is 0.85, with an R^2 of 0.76.

5.6 Other models

In this section, we first consider two benchmarks for model comparison, which are alternatives to the PBE benchmark that we have focused most of our attention on. Then we extend the team equilibrium framework to allow for risk aversion, and report the results of estimation of a team equilibrium risk aversion model, assuming constant absolute risk aversion.

5.6.1 Two benchmarks for model comparison

The No Information Benchmark (NI)

Suppose that one is trying to predict behavior in these four crisis bargaining games, and all one knows is that, in the unique PBE of each game, the strong player always plays IN and the Weak Player 1 and Player 2 both mix between IN and OUT. Without any further information about how the payoffs vary across the games, the principle of insufficient reason suggests that a natural prediction for each of the four games would be that weak player 1 and player 2 will each choose IN half the time, i.e., they mix $50-50$ between IN and OUT. We call this the *No Information* (NI) benchmark.

The log likelihood of the data under the NI model is trivial to compute and is equal to -4770.2 (column 5 of Table 3). This null model significantly outperforms the fit of PBE model, which has a log likelihood equal to -4817.8 (column 1 of Table 3). The PBE is soundly rejected in favor of the random guessing model. The team equilibrium model, in contrast leads to a very large and highly significant improvment over the NI benchnmark, with a log likelihood equal to -4357.2 (column 3 of Table 3).[22]

The Perfect Fit Benchmark (PF)

While the NI benchmark provides what can be considered a reasonable lower bound on the performance of any plausible model of aggregate behavior, a benchmark for the best possible model of aggregate behavior would be one that is *omniscient*, in the sense that it perfectly predicts that aggregate choice probabilities of both player 1 and player 2 in each of the four games. We call this omniscient model the *Perfect Fit* (PF) benchmark. For our games, this benchmark specifies IN vote probabilities that exactly match the IN probabilities of the data. This 24-parameter idealized model correctly predicts the choice probabilities of both weak player 1s and player 2s in all four games and all three collective choice treatments. No other model of aggregate behavior, with any unlimited number of estimated parameters can improve on this. The log likelihood the for PF model is -4163.1.

One can asses a rough measure of fit by comparing the increase in the value of the log likelihood of the team equilibrium relative to the NI model to the increase in the the value of the log likelihood of the PF model relative to the NI model. Analogous to McFadden's pseudo R-squared for logit regressions, we compute this measure of fit as:

$$\begin{aligned} Fit_{TE} &= \frac{1-(\frac{lnL1_{TE}}{lnL1_{NI}})^2}{1-(\frac{lnL1_{PF}}{lnL1_{NI}})^2} \\ &= \frac{0.087}{0.127} \\ &= 0.685 \end{aligned}$$

The numerator of Fit_{TE} represents the reduction in error of the Team Equilibrium model

[22] The NI model is actually nested in the Team Equilibrium model, since it corresponds to $\lambda = 0$.

(TE) relative to the null (NI) model. This is normalized by the denominator which is the reduction in error of the Perfect Fit model (TE) relative to the null (NI) model. For comparison, this measure of fit produces a *Fit* measure of 0 for the NI model and 1 for the PF model.

5.6.2 Risk Aversion

In our model of crisis bargaining, teams choose between a safe option OUT, which yields a guaranteed payoff, and a risky option IN, which yields a binary lottery over a lower and higher payoff. Risk preferences should therefore be relevant for strategic decision-making in this game.

The team equilibrium model can easily allow for risk aversion without further augmentation. Here we consider a model of homogeneous constant relative risk aversion. Accordingly, each payoff, x, in the game is replaced by $u(x) = \frac{x^{(1-\rho)}}{1-\rho}$, with ρ denoting the coefficient of relative risk aversion. Otherwise the team equilibrium model is the same, with individual team members following logit quantal responses to the expected *utility* of IN and OUT.

Hence the team member vote probabilities are given by:

$$
\begin{aligned}
v_{1S}^{n*} &= \frac{e^{\lambda[p_2^{n*}u(a+s)+(1-p_2^{n*})u(a)]}}{e^{\lambda[p_2^{n*}u(a+s)+(1-p_2^{n*})u(a)]} + e^{-\lambda u(a)}} \\
v_{1W}^{n*} &= \frac{e^{\lambda[p_2^{n*}u(-a-s)+(1-p_2^{n*})u(a)]}}{e^{\lambda[p_2^{n*}u(-a-s)+(1-p_2^{n*})u(a)]} + e^{-\lambda a}} \\
v_{2}^{n*} &= \frac{e^{\lambda[\mu^{n*}u(-a-r)+(1-\mu^{n*})u(a+r)]}}{e^{\lambda[\mu^{n*}u(-a-r)+(1-\mu^{n*})u(a+r)]} + e^{-\lambda u(a)}}.
\end{aligned}
$$

where $u(x) = \frac{x^{(1-\rho)}}{1-\rho}$, with ρ denoting the coefficient of relative risk aversion. The team decision probabilities given vote probabilities remains the same, and a team equilibrium with risk aversion is again a fixed point of this system of equations. We estimate this team equilibrium and risk aversion model (TE + RA), and also a model with homogeneous CRRA risk preferences and no payoff disturbances (i.e., PBE with risk aversion), both using maximum likelihood estimation. As with the earlier team equilibrium estimates, we exclude strong first mover data. The estimates are presented in Table 3, along with the log-likelihood and mean squared error for each of the models.

When risk aversion is estimated without error (i.e., $\lambda = \infty$), the estimated risk aversion coefficient is *negative*, indicating risk seeking behavior, which is implausible. This risk aversion without error model corresponds to PBE with homogeneous risk seeking player population.[23]

When risk aversion added onto the team equilibrium model (i.e., $\lambda < \infty$), we the estimated coefficient of relative risk aversion is $\rho = 0.485$, which is approximately quadratic utility, similar to estimates that have been obtained in other experiments.[24]. The estimated value of λ is slightly higher, which is related to how the utility curvature rescales the payoffs of the game.

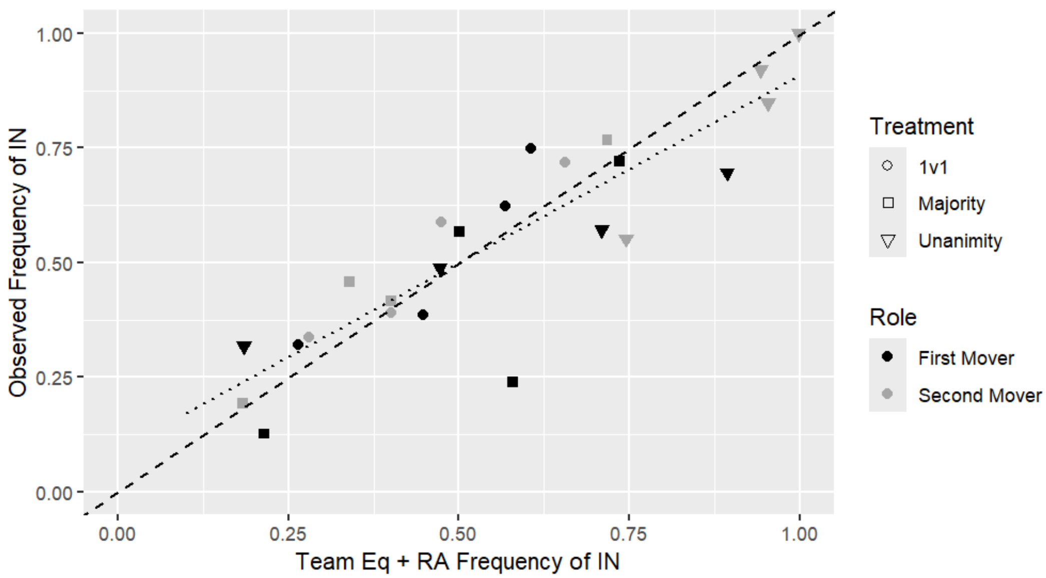


Figure 9: Team Equilibrium Fit with Risk Aversion

While the fit of the team equilibrium model improves somewhat if we allow for risk aversion, it has virtually the same qualitative implications for the team decision frequencies as the team equilibrium model with risk neutrality. This can be seen by comparing the scatter plot of Figure 8 to Figure 9, which are very similar. The intercept of the OLS regression line for the team equilibrium with risk aversion is 0.09 and the slope is 0.82, with an R^2 of 0.77, which is nearly identical to the OLS regression without risk aversion. This shows that the heterogeneity between team members built into the team equilibrium model

[23]The PBE model with risk aversion, while fitting slightly better than the PBE model with risk neutrality, nonetheless still fits worse than the NI model of random guessing.

[24]See, for example, Goeree et al. (2002) and Goeree et al. (2003)

is the key to making sense of the large, systematic deviations from PBE behavior. The effect of risk aversion is second-order.

6 Conclusion

The application of a unitary rational actor model to analyze crisis decision-making in international conflict situations has been sharply criticized, on account of the diversity of interests in group decision-making and organizational rules that constrain how these diverse interests are aggregated into a group decision. Crisis bargaining games capture three essential features of these conflict environments - asymmetric information, sequential timing, and strategic calculation - and thus provide a valuable paradigm for analyzing these situations.

In this paper, we apply the team equilibrium solution concept to these games, which is a general framework that extends the standard single-actor equilibrium analysis of games by incorporating both diversity of team members' interests and organizational rules into the group decision-making process. For this class of games, the team equilibrium approach leads to sharp differences from the standard PBE model of behavior, in terms of both predicted group decisions and crisis outcomes.

The laboratory experiment demonstrates these sharp differences, using four different payoff variations from a simple class of crisis bargaining games. The four games were carefully selected because they represent four canonical PBE predictions about bluffing and bluff-calling behavior by first and second movers, respectively: in game 2, PBE predicts that both players should choose IN less than half the time; in game 4, both players should choose IN more than half the time; in game 1, only player 2 chooses IN more than half the time; and in game 3 only the first mover chooses IN more than half the time.

The experimental evidence highlights the limitations of PBE for understanding behavior and predicting outcomes in crisis bargaining situations. The striking systematic deviations from PBE predictions reported here underscore the need to move beyond unitary actor models of strategic situations involving teams of decision makers. These deviations align closely with the team equilibrium framework, which captures the systematic, payoff-driven patterns of team behavior that are responsive to the collective choice rules used by the groups. Notably, while teams exhibit "more rational" behavior — with group decisions aligning more responsively to payoffs — this does not necessarily result in decisions that are closer to PBE predictions.

This study has significant implications for understanding strategic decision-making. First, it demonstrates that group decision-making in crisis bargaining cannot be adequately modeled by standard game-theoretic approaches that rely on unitary rational actors. By integrating the diversity of interests and the impact of collective choice rules, the team equilibrium framework offers a more nuanced and accurate representation of group behavior in strategic contexts.

Second, the findings emphasize the critical role of institutional structures in shaping collective decisions. Variations in group size and voting rules systematically influence behavior and outcomes, highlighting the importance of organizational design in strategic interactions. For policymakers and institutions managing crises, this points to the need to carefully consider how decision-making processes and rules impact group behavior, particularly in high-stakes strategic situations.

The robustness of the team equilibrium model across different payoff structures and decision-making rules opens promising avenues for further research. Future work could explore how factors such as communication within teams, the role of leadership, and heterogeneity in team members' payoffs shape outcomes. Extending this framework to more complex strategic interactions could offer deeper insights into how groups navigate uncertainty and strategic conflict.

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Appendices

Appendix 1: Experimental Design Details

Table 4: Summary of Sessions

SESSION#	TREATMENT	#SUBJECTS	LOCATION
1	1×1	18	Online UCI
2	1×1	20	Online UCI
3	1×1	10	Online UCI
4	1×1	14	Online UCI
5	1×1	14	Online UCI
6	1×1	12	Online UCI
7	1×1	18	UCI
8	1×1	8	UCI
9	5×5 Majority	20	UCI
10	5×5 Majority	20	Online UCI
11	5×5 Majority	20	UCSB
12	5×5 Majority	20	UCSB
13	5×5 Majority	20	UCSB
14	5×5 Majority	20	UCSB
15	5×5 Unanimity	20	UCI
16	5×5 Unanimity	20	UCI
17	5×5 Unanimity	20	UCI
18	5×5 Unanimity	20	UCSB
19	5×5 Unanimity	20	UCSB

Figure 10: Game Payoffs

(a) Payoffs for Game 1:

First Mover Team's Choice of Action	OUT	10,35

If HEADs was selected by coin flip

		Second Mover Team's Choice of Action	
		OUT	IN
First Mover Team's Choice of Action	IN	30,15	35,10

If TAILs was selected by coin flip

		Second Mover Team's Choice of Action	
		OUT	IN
First Mover Team's Choice of Action	IN	30,15	5,40

(b) Payoffs for Game 2:

First Mover's Choice of Action	OUT	20,32

If HEADs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	28,24	44,20

If TAILs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	28,24	4,36

(c) Payoffs for Game 3:

First Mover's Choice of Action	OUT	21,27

If HEADs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	27,21	42,6

If TAILs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	27,21	6,42

(d) Payoffs for Game 4:

First Mover's Choice of Action	OUT	20,32

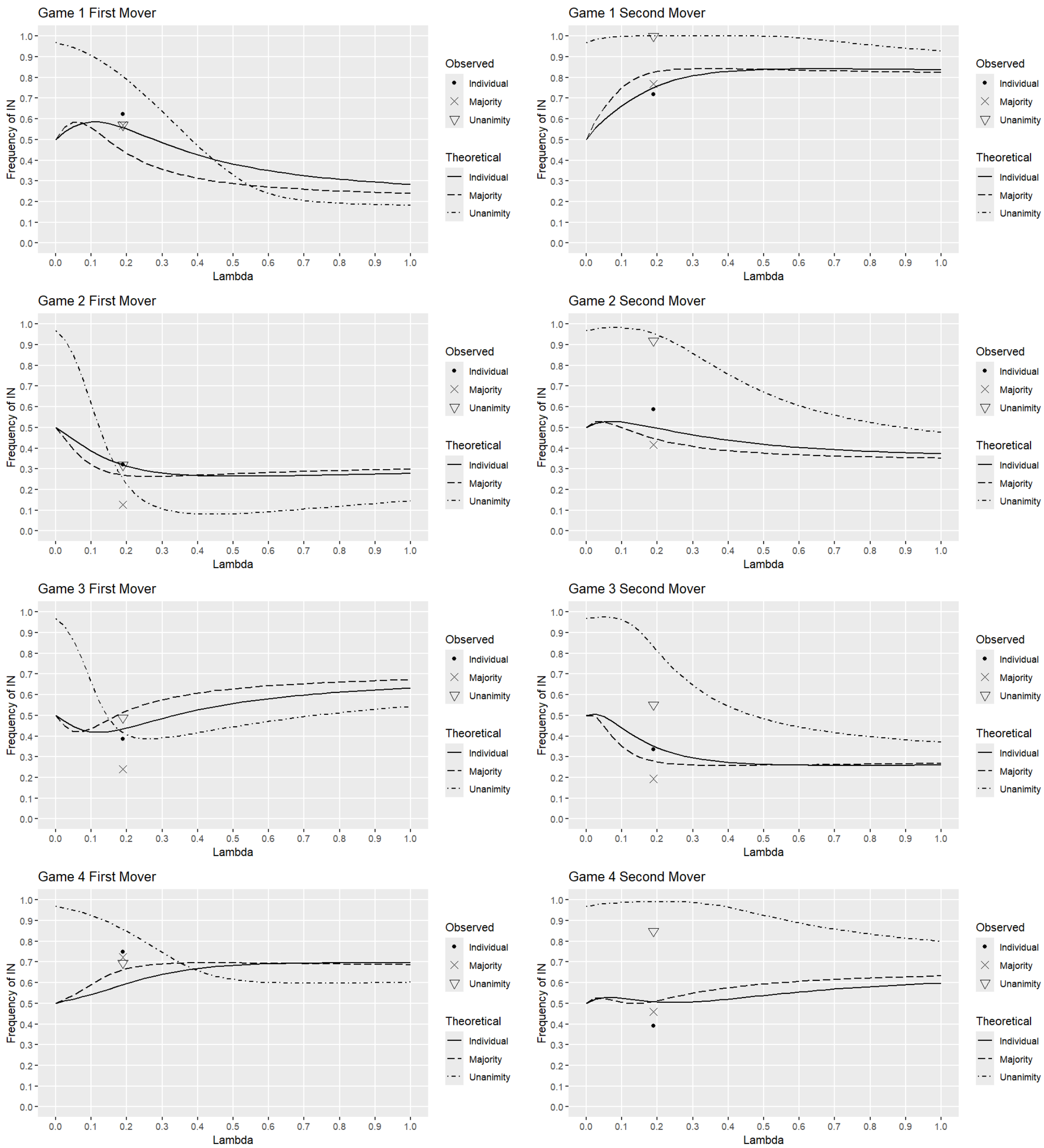
If HEADs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	28,24	32,8

If TAILs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	28,24	16,48

Appendix 2: Observed and Theoretical Decision Frequencies



Each panel of the above figure displays the team equilibrium for one game and one player role. Each line traces out the team equilibrium for one team treatment, for all λ values from 0 to 1. The points are plotted on the x-axis at the estimated value of λ, and on the y-axis at the observed team decision frequency.

Online Appendix: Instructions and screenshots

Sample instructions

These are the instructions used for the 1-1 in-person experiments with the reverse game order (4321). Modifications for the 5-5 majority rule treatment is noted in double brackets at the appropriate places. Instructions for the unanimity rule treatment were nearly identical to the majority rule instructions, with the exception of the voting rule explanation. The instructions were handed out to all subjects so they could follow along while the experimenter read the instructions aloud. They could also refer back to the instructions during the experiment if they wished.

For the team experiments, these instructions were slightly modified to explain that each subject's action choice was a *vote* of IN or OUT and all final team decisions was determined by majority [unanimity] rule. The instructions for online sessions included an explanation of the procedures that would be followed in case any subject became disconnected. The online sessions were conducted on Zoom and also used a utility software, Experimentalist, which streamlined the login, connection, and payoff protocols.

General instructions

Thank you for coming. You are about to participate in an experiment on decision-making. Your earnings will depend partly on your decisions, partly on the decisions of others, and partly on chance. This experiment requires your undivided attention. Please refrain from other activities for the duration of the experiment.

The entire session will take place through computer terminals, and all interaction between participants will take place through the computers. Please do not attempt to communicate in any way with other participants during the experiment.

Some of your decisions will be randomly selected for payment. Your earnings are denominated in points, and each point has a value of $0.20. In other words, every 100 points generates $20 in earnings for you. In addition to your earnings from decisions, you will receive a show-up fee of $7, and a completion fee of $5. At the end of the experiment, your earnings will be rounded up to the nearest dollar amount. All your earnings will be paid by cash.

Main task

Overview of the experiment:

This experiment consists of 4 matches, and each match has 10 rounds. We will now review the instructions for match 1. After the conclusion of each match, instructions for the next match will be read.

Type: First mover and Second mover

At the beginning of the experiment, you will be randomly assigned to one of two types: First mover or Second mover. Once you become a first mover or a second mover, your type will remain fixed throughout the entire experiment. As will be explained later, in every round, first movers make a decision first, and then second movers follow.

Matching and decision

At the beginning of each round, you will be randomly paired with another subject of the opposite type. If you are a first mover, you will be paired with a second mover, and vice versa. In each round, when it is your turn to move, you will make a decision to choose an action (IN or OUT).

[[*Team Assignment*

At the beginning of each round, first movers will be randomly sorted into first mover teams, and second movers will be randomly sorted into second mover teams. Each team has 5 members with the same type. In each round, your 5-member team will be randomly paired with another 5-member team of the opposite type. If your team is a first mover team, your team will be paired with a second mover team, and vice versa.]]

[[*Team Decision*

In each round, when it is your team's turn to move, your team will make a collective decision to choose an action (IN or OUT). You will be asked to vote for an action in each round, and your team decision will be determined by majority rule. For instance, if there are 2 member of your team who votes for action In and 3 members who vote for action Out, then your team's collective decision will be action Out.]]

Payoff table

Payoff table

		Second Mover's Choice of Action	
First Mover's Choice of Action	IN	OUT	IN
		1000, 220	40, 505

On the decision-making screen, you will see three tables that show the payoffs in points from each combination of choices. The payoffs in the example table above are only for illustration, they are not the actual payoffs used in the experiment. The rows always correspond to the actions the first mover [[first mover team]] can choose, and the columns correspond to the actions the second mover [[second mover team]] can choose. The first entry in each cell represents the first mover's [[first mover team members']] earnings, while the second entry represents the earnings of the second mover [[second mover team members]]. For instance (1) if the first mover [[team]] chooses action IN and the second mover [[team]] chooses action OUT, the first mover receives [[each of the first mover team members receives] 1000 points, while the second mover [[each of the second mover team members]] receives 220 points. (2) if the first mover [[team]] chooses action IN and the second mover [[team]] chooses action IN, the first mover receives [[each of the first mover team members receives]] 40 points, while the second mover receives [[each of the second mover team members receives]] 505 points.

Coin flip: HEADs or TAILs

There will be three different payoff tables on your screen, one upper table and two lower tables. At the beginning of each round, the computer flips a virtual, fair coin which determines either HEADs or TAILs. The probability that HEADs (or TAILs) is selected is 50%. A separate virtual, fair coin is flipped for each round, for each pairing. The result of each coin flip is independent of every other coin flip.

If the result of the coin flip is HEADs, then, among the two lower tables, the table on the left side of the screen shows the true payoffs to each combination of actions. If the result is TAILs, then the table on the right shows the true payoffs. As will be explained later, the upper payoff table is not related to the coin flip result. Only the first mover [[first mover team members]] knows [[know]] whether HEADs or TAILs has been selected before he chooses an action [[they vote]]. The second mover [[second mover team members]] only learns [[learn]] this information at the end of the round, after all decisions have been made. This will be further explained in detail below.

Decision-making procedures

There are three stages of decision-making procedures-(1) action choice of the first mover [[voting of the first mover team members]], (2) action choice of the second mover [[voting of the second mover team members]], and (3) feedback about decisions and payoffs. We will now review each of these stages by looking at screenshots of the actual experimental user interface. All payoffs in these screenshots are the real payoffs used in match 1.

(The screenshots were handed out to subjects and they followed along as the experimenter read the following script. Copies of the screenshots are reproduced at the end of this appendix.)

(1) Action choice of the first mover First mover: [Slide 1] On the first screen, the first mover [[first mover team members]] will see three tables that show the payoffs in points from each combination of actions and a random computerized coinflip. The top table, which has one row and two cells, shows the payoffs resulting from the first mover [[first mover team]] choosing action OUT. If the first mover [[first mover team]] chooses action OUT, the round immediately ends and subjects receive the payoffs shown in this table. That is, regardless of the result of the coin flip, the first mover [[first mover team members]] receives 10 points, while the second mover [[second mover team members]] receives 35 points. The bottom two tables show the payoffs if the first mover [[first mover team members]] chooses action IN, for every combination of computerized coin flip and action of the second mover. The first mover [[first mover team members]] can choose [[vote for]] an action by clicking a row in the payoff tables. To finalize a choice [[vote]], the "Submit" button highlighted in red should be clicked.

Second mover: [Slide 2] The second mover [[second mover team members]] will wait for the first mover [[first mover team members]] to choose [[vote for]] an action. On this screen, the computer's random selection of HEADs or TAILs will not be revealed to the second mover [[second mover team members]].

(2) Action choice of the second mover. First mover: [Slide 3] This screen appears only if the first mover [[first mover team]] chooses IN. The first mover [[first mover team]] is asked to wait for the second mover [[second mover team]] to choose an action in the two payoff tables below. Choosing [[voting for]] an action, the second mover [[second mover team members]]

does [[do]] not know whether HEADs or TAILs was randomly selected.

Second mover: [Slide 4] This screen appears only if the first mover [[first mover team]] chooses IN. The second mover is asked to choose an action in the two payoff tables below. Choosing [[voting for]] an action, the second mover [[second mover team members]] does not know whether HEADs or TAILs was randomly selected. The second mover [[second mover team members]] can choose an action by clicking a column in the payoff tables. To finalize a choice, the "Submit" button highlighted in red should be clicked.

(3) Receiving feedback about the payoffs

First mover: [Slide 5] This is the feedback screen for the case in which OUT was chosen by the first mover [[first mover team]]. The first mover [[first movers]] and the second mover [[second movers]] will receive feedback about their payoffs and the computer's random choice of HEADs or TAILs.

[Slide 6] This is the feedback screen for the case in which IN was chosen by the first mover. The action of each is highlighted, and the payoffs you will receive are highlighted in pink. The computer's random choice of HEADs or TAILs will also be revealed to the second mover.

Second mover: [Slide 7] This is the feedback screen for the case in which OUT was chosen by the first mover [[first mover team]]. The first mover[[s]] and the second mover[[s]] will receive feedback about their payoffs and the computer's random choice of HEADs or TAILs.

[Slide 8] This is the feedback screen for the case in which IN was chosen by the first mover [[first mover team]]. The computer's random choice of HEADs or TAILs will also be revealed to the second mover [[second mover team]]. For the randomly selected payoff table, the action of each mover is highlighted, and the payoffs you will receive are highlighted in purple. On the feedback screen, all subjects should click the "Confirm" button to advance the page.

Payoffs

At the end of the experiment, one round from each Match (4 rounds in total) will be randomly selected for determining the payment of each subject. The rounds chosen may be different for different subjects. You will be paid the amount of points you earned in the rounds randomly selected for you.

Quiz

For your comprehension, before Match 1 begins, you will be asked to solve quiz problems. You can participate in the experiment only if you enter correct answers for all problems.

Summary of instructions

1. At the beginning of the experiment, you will be randomly assigned to one of two types: First mover or Second mover. Once you become a first mover or a second mover, your type will remain fixed throughout the entire experiment.

2. Each of the 4 matches has 10 rounds.

3. At the beginning of each round, you will be randomly paired with a subject of the other type. In each round, when it is your turn, your will choose an action. [[At the beginning of each round, you will be randomly sorted into a team of subjects with the same type, and your team will be randomly paired with another team of the other type. In each round, when it is your team's turn to move, your team will make a collective decision to choose an action.]]

4. If the first mover [[team]] chooses OUT, the round is over and the second mover does [[team member do]] not make a choice. The payoffs do not depend on the result of the coin flip.

5. If the first mover [[team]] chooses In, the second mover [[team members vote for]] chooses an action in the two payoff tables below. After all members of both teams have voted in their turn, the outcome of the coin flip of HEADs or TAILs and each team's choice will determine the payoffs.

First Mover's Choice of Action	OUT	20,32

If HEADs was selected by coin flip

	Second Mover's Choice of Action		
		OUT	IN
First Mover's Choice of Action	IN	28,24	32,8

If TAILs was selected by coin flip

	Second Mover's Choice of Action		
		OUT	IN
First Mover's Choice of Action	IN	28,24	16,48

Match 1 payoffs

[Subjects answer comprehension questions, after which the first round of Match 1 begins. After 10 rounds, the experiment is paused and the experimenter reads the next script to announce the change of payoffs for Match 2.]

Match 2

We have reached the end of match 1 and match 2 will now begin. The rules and procedures used in this match are exactly the same as in the first match. However, the payoffs are now different. The new payoff tables are pasted at the bottom of this page, below the instructions summary.

Summary of instructions

1. At the beginning of the experiment, you will be randomly assigned to one of two types: First mover or Second mover. Once you become a first mover or a second mover, your type will remain fixed throughout the entire experiment.

2. Each of the 4 matches has 10 rounds.

3. At the beginning of each round, you will be randomly paired with a subject of the other type. In each round, when it is your turn, your will choose an action. [[At the beginning of each round, you will be randomly sorted into a team of subjects with the same type, and your team will be randomly paired with another team of the other type. In each round, when it is your team's turn to move, your team will make a collective decision to choose an action.]]

4. If the first mover [[team]] chooses OUT, the round is over and the second mover does [[team member do]] not make a choice. The payoffs do not depend on the result of the coin flip.

5. If the first mover [[team]] chooses In, the second mover [[team members vote for]] chooses an action in the two payoff tables below. After all members of both teams have voted in their turn, the outcome of the coin flip of HEADs or TAILs and each team's choice will determine the payoffs.

First Mover's Choice of Action	OUT	21,27

If HEADs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	27,21	42,6

If TAILs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	21,27	6,42

Match 2 payoffs

[After 10 rounds, the experiment is paused and the experimenter reads the following script to announce the change of payoffs for Match 3.]

Match 3

We have reached the end of match 2 and match 3 will now begin. The rules and procedures used in this match are exactly the same as in the previous match. However, the payoffs are now different. The new payoff tables are pasted at the bottom of this page, below the instructions summary.

Summary of instructions

1. At the beginning of the experiment, you will be randomly assigned to one of two types: First mover or Second mover. Once you become a first mover or a second mover, your type will remain fixed throughout the entire experiment.

2. Each of the 4 matches has 10 rounds.

3. At the beginning of each round, you will be randomly paired with a subject of the other type. In each round, when it is your turn, your will choose an action. [[At the beginning of each round, you will be randomly sorted into a team of subjects with the same type, and your team will be randomly paired with another team of the other type. In each round, when it is your team's turn to move, your team will make a collective decision to choose an action.]]

4. If the first mover [[team]] chooses OUT, the round is over and the second mover does [[team member do]] not make a choice. The payoffs do not depend on the result of the coin flip.

5. If the first mover [[team]] chooses In, the second mover [[team members vote for]] chooses an action in the two payoff tables below. After all members of both teams have voted in their turn, the outcome of the coin flip of HEADs or TAILs and each team's choice will determine the payoffs.

First Mover's Choice of Action	OUT	20,32

If HEADs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	28,24	44,20

If TAILs was selected by coin flip

		Second Mover's Choice of Action	
		OUT	IN
First Mover's Choice of Action	IN	28,24	4,36

Match 3 payoffs

[After 10 rounds, the experiment is paused and the experimenter reads the following script to announce the change of payoffs for Match 4.]

Match 4

We have reached the end of match 3 and match 4 will now begin. The rules and procedures used in this match are exactly the same as in the previous match. However, the payoffs are now different. The new payoff tables are pasted at the bottom of this page, below the instructions summary.

Summary of instructions

1. At the beginning of the experiment, you will be randomly assigned to one of two types: First mover or Second mover. Once you become a first mover or a second mover, your type will remain fixed throughout the entire experiment.

2. Each of the 4 matches has 10 rounds.

3. At the beginning of each round, you will be randomly paired with a subject of the other type. In each round, when it is your turn, your will choose an action. [[At the beginning of each round, you will be randomly sorted into a team of subjects with the same type, and your team will be randomly paired with another team of the other type. In each round, when it is your team's turn to move, your team will make a collective decision to choose an action.]]

4. If the first mover [[team]] chooses OUT, the round is over and the second mover does [[team member do]] not make a choice. The payoffs do not depend on the result of the coin flip.

5. If the first mover [[team]] chooses In, the second mover [[team members vote for]] chooses an action in the two payoff tables below. After all members of both teams have voted in their turn, the outcome of the coin flip of HEADs or TAILs and each team's choice will determine the payoffs.

First Mover Team's Choice of Action	OUT	10,35

If HEADs was selected by coin flip

		Second Mover Team's Choice of Action	
		OUT	IN
First Mover Team's Choice of Action	IN	30,15	35,10

If TAILs was selected by coin flip

		Second Mover Team's Choice of Action	
		OUT	IN
First Mover Team's Choice of Action	IN	30,15	5,40

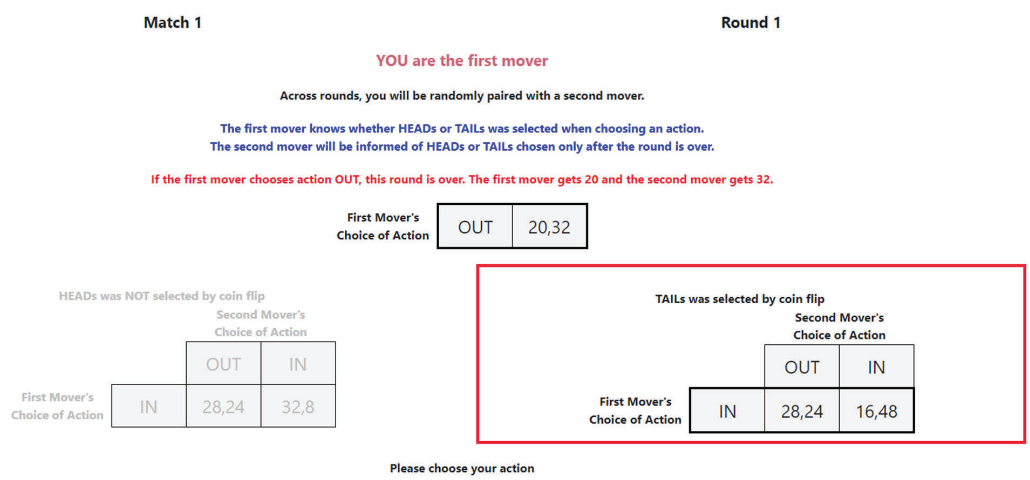
Match 4 payoffs

End of Experiment (Read after Match 4 ends): We have reached the end of match 4. Thank you for your participation. Please take your time to review your randomly payoff on this screen. When you are ready, please click the confirm button and enter your Venmo username on the next screen for payment. For security reasons, please close your browser after entering your Venmo username. This concludes the experiment, thank you for your participation.

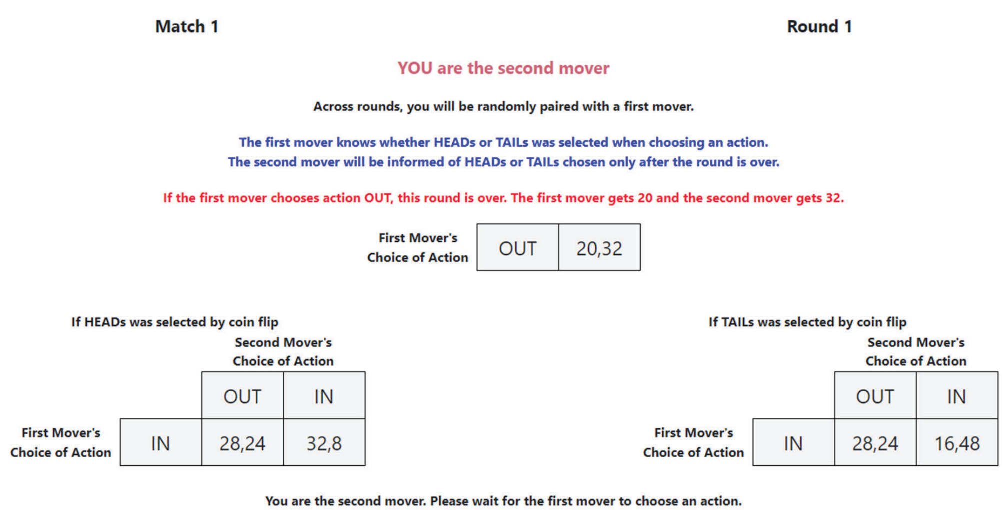
Screenshot slides

These are the slides referred to in the instructions and distributed as handouts to subjects for the 1-1 sessions. The slides for the 5-5 sessions were similar, except for including the voting outcomes of each team in the results screen and minor wording changes to be consistent with teams instead of individuals.

Slide 1



Slide 2



Slide 3

Match 1 **Round 1**

YOU are the first mover

Across rounds, you will be randomly paired with a second mover.

The first mover knows whether HEADs or TAILs was selected when choosing an action.
The second mover will be informed of HEADs or TAILs chosen only after the round is over.

If the first mover chooses action OUT, this round is over. The first mover gets 20 and the second mover gets 32.

First Mover's Choice of Action		
	OUT	20,32

HEADs was NOT selected by coin flip

	Second Mover's Choice of Action	
First Mover's Choice of Action	OUT	IN
IN	28,24	32,8

TAILs was selected by coin flip

	Second Mover's Choice of Action	
First Mover's Choice of Action	OUT	IN
IN	28,24	16,48

You chose action IN in this round.
You are the first mover. Please wait for the second mover to choose an action.

Slide 4

Match 1 **Round 1**

YOU are the second mover

Across rounds, you will be randomly paired with a first mover

The first mover knows whether HEADs or TAILs was selected when choosing an action.
The second mover will be informed of HEADs or TAILs chosen only after the round is over.

If the first mover chooses action OUT, this round is over. The first mover gets 20 and the second mover gets 32.

First Mover's Choice of Action		
	OUT	20,32

If HEADs was selected by coin flip

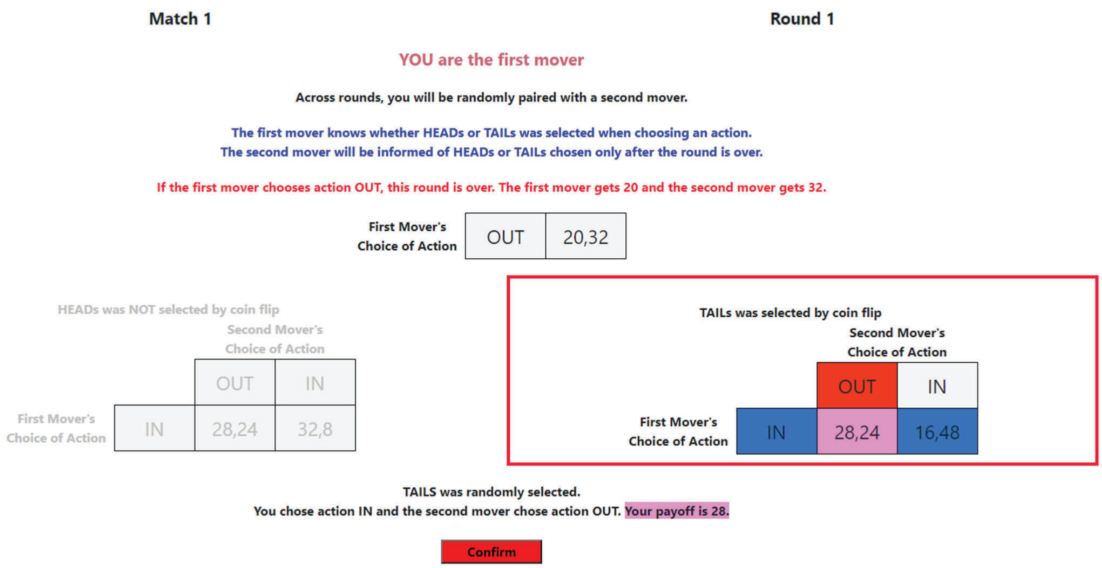
	Second Mover's Choice of Action	
First Mover's Choice of Action	OUT	IN
IN	28,24	32,8

If TAILs was selected by coin flip

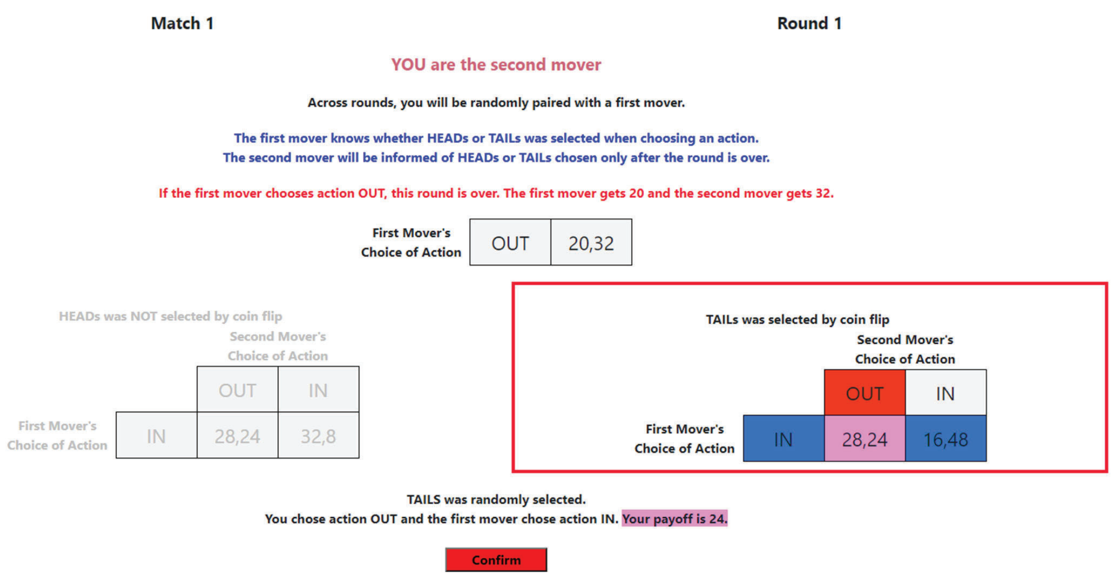
	Second Mover's Choice of Action	
First Mover's Choice of Action	OUT	IN
IN	28,24	16,48

Please choose an action.

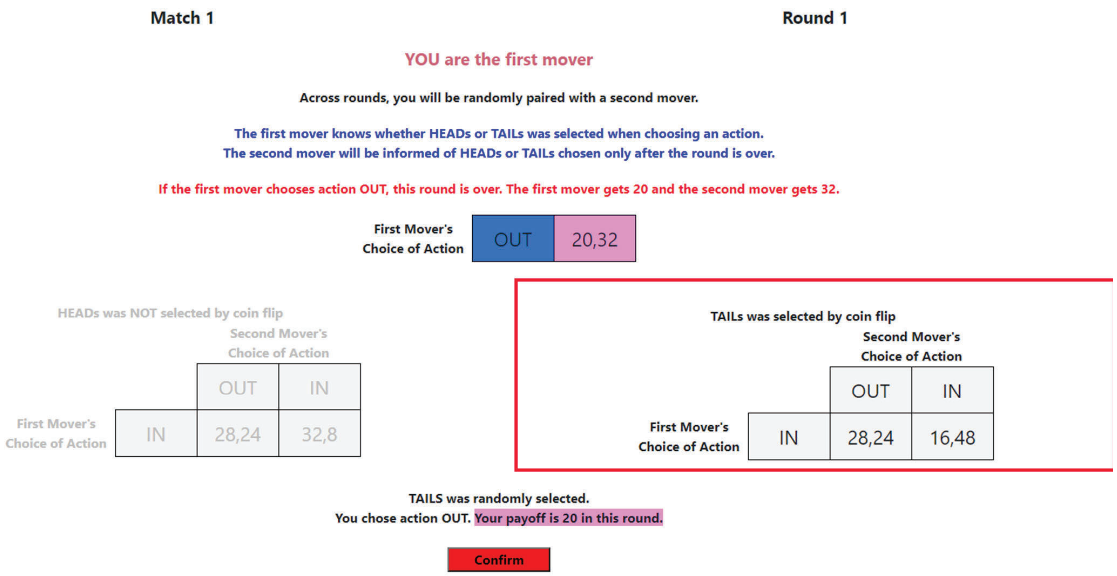
Slide 5



Slide 6



Slide 7



Slide 8