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AN EXPERIMENTAL NASH PROGRAM: A COMPARISON OF STRUCTURED V.S. SEMI-STRUCTURED BARGAINING EXPERIMENTS

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An experimental Nash program: A comparison of structured v.s. semi-structured bargaining experiments

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Abstract

While the market design advocates the importance of good design to achieve desirable properties, experiments on coalition formation theory have shown fragility in proposed mechanisms to do so. We experimentally investigate the effectiveness of "structured" mechanisms that implement the Shapley value as an ex-ante equilibrium outcome with those of corresponding "semi-structured" bargaining procedures. We find a significantly higher frequency of the grand coalition formation and the higher efficiency in the semi-structured than in the structured procedure regardless of whether it is demand-based or offer-based. While significant differences in the resulting allocations are observed between the two structured procedures, little difference is observed between the two semi-structured procedures. Finally, possibility of free-form chat induces the equal division more frequently than without it. Our results suggest, when it comes to bargaining and coalition formation, not having various restrictions imposed by different mechanisms may lead to more desirable outcomes.

JEL code: C70, C71, C92
Keywords: Nash Program, Bargaining procedures, Shapley value

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1 Introduction

For decades, economists, particularly game theorists, have gained a crucial role in assisting legislators, regulators, lawyers, and judges in designing markets. They have been instrumental in developing complex markets such as in the classical theory of auctions (Vickrey, 1961; Milgrom and Weber, 1982a,b), in labor clearing houses for American doctors getting their first jobs (Roth and Peranson, 1999), or markets for electric power (Wilson, 2002; Cramton, 2017). Additionally, they have proposed allocation procedures for markets that do not use prices, such as coalition formation (Kahan and Rapoport, 2014), school choice (Roth, 1985), live-donor kidney transplantation (Roth et al., 2004, 2007) or the job market for new economists (Coles et al., 2010). The common and well-established vision in the literature is that "*design is important because markets don't always grow like weeds–some of them are hothouse orchids*" (Roth, 2002, p. 1373). Without external intervention, in fact, markets naturally struggle to provide desirable properties such as thickness, efficiency, safety, and simplicity.

Bargaining is one of the most ubiquitous and effective forms of market interaction between potentially conflicting or cooperating agents, at the basis of many of the situations listed above. Thus, bargaining interactions, among others, may particularly benefit from the potential welfare gains of well-designed procedures. As such, the importance of bargaining research for enhancing the efficiency – and the many other desirable properties – of these interactions has been widely emphasized (Crawford, 1982).

Over the years, experimental economics has become a natural complement to theoretical work, aiding in understanding market failures and testing new solutions before proposing them to policymakers (Kagel and Levin, 1986; Kagel and Roth, 2000). Then, the goals achieved through extensive theoretical research on mechanism design – among which bargaining procedures design – have been well-supported and documented by a growing body of experimental literature (Brosig et al., 2003; Chen and Sönmez, 2006; Cox et al., 1988; Denton et al., 2001; Smith, 1967) and numerous field applications (Dickerson et al., 2012). However, there is a field where experiments have shown a certain fragility in validating the proposed theoretical mechanisms and their appealing results: coalition formation theory (Abe et al., 2021; Okada and Riedl, 2005).

Coalitions are means oriented, often temporary, alliances among individuals or groups who may have different initial goals. In many situations, forming a coalition is both individual and group advantageous. Coalition formation behavior is a pervasive aspect of social life (Gamson, 1961) and thus a crucial matter in economics (Kahan and Rapoport, 2014; Konishi and Ray, 2003). A theory of coalition formation has been developed in many models coming from different disciplines, such as mathematics, in the theory of cooperative games, then widely adopted not only in economics and political science (Holler, 1982), but also in models in management (Stevenson et al., 1985), social psychology (Komorita and Kravitz, 1983) and computer science (Dang et al., 2006).

In this paper, we focus on the matter of coalition formation from the classical perspective of game theorists, thanks to the means of cooperative game theory. This theory emerged alongside noncooperative game theory thanks to the seminal paper by von Neumann (1928). Then by the active collaboration of John von Neumann together with Oskar Morgenstern, culminated in the renowned book *Theory of Games and Economic Behavior* (von Neumann and Morgenstern, 1944). Despite a common origin founded on the well-established assumption of rationality of individuals, however, noncooperative game theory and cooperative game theory have advanced for decades on two different paths, incrementing a gap that has become more and more apparent over the years.

Cooperative game theory primarily seeks to answer two fundamental questions:

What coalitions will form (thus, originating coalition formation studies), and how will their members share the proceeds? (Maschler, 1992). The Nash program (Nash, 1953) offers a noncooperative foundation for addressing both questions, thereby creating a natural bridge between the two related but distinct theories. The Nash program is based on describing mechanisms, mostly in the form of strategic bargaining procedures, to lead individuals to cooperation. The theory predicts that individuals, guided by the proposed mechanisms in their interactions, will manage to cooperate in the most efficient way and share the proceeds according to well-known cooperative solutions. While many authors have contributed to the development of the Nash program (see, Serrano, 2005, 2008, 2014, 2021, for surveys), so in line with the previously illustrated common opinion on the importance of investing in research in bargaining, experimental investigations, in the specific context of the Nash program, have been scarce.

To address this gap in the literature, Chessa et al. (2022, 2023a,b) have conducted a series of experiments comparing different mechanisms. These mechanisms are theoretically expected to implement full cooperation in games where rationality would lead individuals to choose cooperative strategies and share the proceeds according to the Shapley value, the most well-known cooperative solution (Shapley, 1953). Even if motivated by different research questions, the common pattern in all these experiments is that, despite the implementation of structured bargaining procedures promising cooperation, unfortunately the experimental results show that individuals, in many cases, fail to cooperate. And these results are in line with other experimental investigations of theoretical models for coalition formation (Kahan and Rapoport, 1980a; Rapoport and Kahan, 1984).

In this study, we aim to shed light on whether reducing the structural constraints in bargaining procedures can lead to higher levels of cooperation among individuals.

Indeed, previous studies have already highlighted the importance of shifting focus towards more unstructured bargaining experiments, advocating for their revival as a future direction in experimental research (Güth, 2012; Karagözoğlu, 2019).

It is, however, difficult to design an "unstructured" computerized bargaining experiment, because the very same design of a computer interface necessary puts some structure into the bargaining procedure. For example, Shinoda and Funaki (2019) conducted what they call a computerized "unstructured" three-player bargaining experiment. Participants could freely propose a coalition and an associated allocation that is feasible among the members of the proposed coalition. Participants were also free to modify their proposal anytime during the negotiation, and also free to agree on the proposal made by another participant. A coalition was formed if all its members agreed. They also considered a treatment in which participants could freely send chat messages to others. Similarly, in three-players games that model negotiable conflicts involving two weak players and one strong player, Kahan and Rapoport (1980b) also considered two communication conditions: namely a condition where subjects could exchange messages, and a condition where subjects were not allowed to send messages and were unaware that they had been denied this option. While these procedures are much less structured compared to those considered in Chessa et al. (2022, 2023a,b), there remain some constraints in what participants could do and how the coalition was formed.

We therefore consider both an offer-based and a demand-based (an alternative procedure where participants, instead of freely proposing a coalition with an associated allocation among its member, freely make their demand for them to join a coalition) "semi-structured" bargaining experiment. We call our experiments "semi-structured" (Duffy et al., 2021) because, as noted above, while they are much less structured compared to the "structured" bargaining experiments considered by Chessa et al. (2022, 2023a,b), there remains some structure in the bargaining procedures.

More specifically, we vary (a) whether or not participants can communicate freely via online chat during the negotiation. This dimension is motivated by Shinoda and Funaki (2019), who found that the grand coalition is more likely to be formed with than without a possibility of free-form communication among players through a chat window. (b) Whether the negotiation is offer-based or demand-based. This second dimension is motivated by Chessa et al. (2023b), who found that demand-based and offer-based mechanism can result in outcomes satisfying much different properties. Then (c) we contrast the results of these "semi-structured" experiments with the results of "structured" experiments of Chessa et al. (2023b), and this represents the third and key motivation of our analysis.

We find that semi-structured experiments, both offer-based and demand-based, result in the higher frequency of grand coalition formation and the efficiency than the structured ones. Unlike Chessa et al. (2023b) who find significant differences in the outcome of an offer-based and a demand-based procedure, we do not find significant differences between the two regardless of the possibility of free-form communication. The latter result is assuring in that, at least for the semi-structured bargaining experiments on the games with non-empty core, exact procedure may have little impact on the outcomes. As a consequence of the lower efficiency of "structured" experiments, we find that the average payoffs deviate significantly from the Shapley values for more players in more games under the "structured" experiments than under the "semi-structured" ones. While investigating for the possible sources of deviation of the realized allocations from the Shapley value, applying the approach of Aguiar et al. (2018), we report that which axioms are violated depend on whether the freeform communication is allowed, and on whether the experiments are offer-based or demand-based. Finally, we observe that the possibility of chat in semi-structured experiments pushes the allocation toward equal sharing.

The rest of the paper is organized as follows. Section 2 illustrate the theoretical background of this paper. Section 3 presents the experimental design. The results are presented and discussed in Section 4. And Section 5 concludes.

2 Theoretical background

2.1 Cooperative TU games and solutions

Let $N = \{1, \ldots, n\}$ be a finite set of *players*. Each subset $S \subseteq N$ is referred to as a *coalition*, with N called the *grand coalition*. A *cooperative transferable utility (TU) game* is defined as a pair (N, v), where N is the set of players and $v : 2^N \to \mathbb{R}$, with $v(\emptyset) = 0$, is the *characteristic function*. This function assigns a *worth* $v(S)$ to each coalition $S \subseteq N$, representing the worth that members of S can achieve through cooperation. When the set of players N is fixed, we denote the game by v instead of (N, v). The set of all games with player set N is denoted by $\mathcal{G}^N$.

Players i and j are *symmetric* in $v \in \mathcal{G}^N$, if $v(S \cup \{i\}) = v(S \cup \{j\})$ for all $S \subseteq N \setminus \{i, j\}$. A player i is a *null player* in $v \in \mathcal{G}^N$ if $v(S) = v(S \setminus \{i\})$ for all $S \subseteq N$.

A game $v \in \mathcal{G}^N$ is called *monotonic* if $v(S) \leq v(T)$ for each $S \subseteq T \subseteq N$, *superadditive* if $v(S) + v(T) \leq v(S \cup T)$ whenever $S \cap T = \emptyset$, with $S, T \subseteq N$, and *convex* if $v(S) + v(T) \leq v(S \cup T) + v(S \cap T)$, for each $S, T \subseteq N$ (with the game being *strictly convex* if the inequality is strict). Another equivalent definition of convexity is that for each $S \subseteq T \subseteq N \setminus \{i\}$, $v(S \cup \{i\}) - v(S) \leq v(T \cup \{i\}) - v(T)$.

In (strictly) convex games, cooperation becomes increasingly advantageous, leading to the formation of the grand coalition. It is important to note that convexity implies superadditivity, which in turn implies monotonicity.

For a game $v \in \mathcal{G}^N$, an *allocation* is an n-dimensional vector $(x_1, \ldots, x_n) \in \mathbb{R}^N$ that assigns an amount $x_i \in \mathbb{R}$ to each player i. For each coalition $S \subseteq N$, we define $x(S) = \sum_{i \in S} x_i$. The *imputation set* is defined as:

$$I(v) = \{x \in \mathbb{R}^n | x(N) = v(N) \text{ and } x_i \geq v(\{i\}) \, \forall i \in N\},$$

which includes all allocations that are *efficient* (i.e. $x(N) = v(N)$) and *individually rational* (i.e. $x_i \geq v(\{i\}) \, \forall i \in N$).

The core is the set of imputations that are also *coalitionally rational*, defined as:

$$C(v) = \{x \in I(v) | x(S) \geq v(S) \, \forall S \subseteq N\}.$$

An allocation within the core is stable in the sense that, if proposed for the grand coalition, no coalition has an incentive to deviate and form its own.

A *solution* is a function $\psi : \mathcal{G}^N \to \mathbb{R}^N$ that assigns an allocation $\psi(v)$ to every game $v \in \mathcal{G}^N$. The most well-known solution concept is the *Shapley value*, which is widely applied in economic models and defined as:

$$\phi_i(v) = \sum_{S \subseteq N, i \in S} \frac{(|S| - 1)!(|N| - |S|)!}{|N|!} (v(S) - v(S \setminus \{i\})) \, \forall i \in N.$$

The Shapley value assigns to each player his/her expected marginal contribution to the coalition of players that entered before him/her given that every order of entrance is equally likely. This concept was defined to satisfy certain fairness criteria, but it is not necessarily within the core. However, if the game is superadditive, the Shapley value is an imputation and, if the game is convex, it belongs to the core.

In our analysis, we will also consider a simpler solution concept, the *Equal Division solution*, which distributes the worth $v(N)$ equally among all players. It is defined as:

$$ED_i(v) = \frac{v(N)}{n} \; \forall i \in N.$$

This solution has been investigated as a compelling option for cooperative players when the worth of coalitions is not a primary consideration.

2.2 Winter and H-MC mechanisms

Winter (1994) introduced a bargaining model based on sequential demands within strictly convex cooperative games. In these games, cooperation becomes increasingly attractive, generating a "snowball effect" that leads to the formation of the grand coalition. Furthermore, in convex games, the Shapley value is a focal point within the core, which is always nonempty. In this model, players take turns publicly announcing their demands. Essentially, each player declares, "I am willing to join any coalition that offers me..." and then waits for these demands to be satisfied by other players. The bargaining process begins with a randomly selected player from the set N, say player i. This player publicly states her demand d_i and then selects a second player, who must also declare her demand. The game continues in this manner, with each player presenting a demand and then selecting another player to take their turn. If at any point a compatible demand is made - meaning there exists a coalition $S \subseteq N$ for which the total demand of the players in S does not exceed $v(S)$ - the first player to make such a demand selects the compatible coalition S. The players in S then receive their demands and exit the game, while the remaining players continue bargaining under the same rules applied to v restricted to $N \setminus S$. In a T-period implementation, where $T > 1$ and T is finite, if any players are left with unmet demands after the first period, the bargaining procedure is repeated in the second period with this subset of players. Their previous demands are canceled, and they incur a fixed delay cost. This process continues until the T periods have been completed. In our analysis, we consider a one-period implementation in which players with unmet demands at the end of the first period receive their individual value considered in Chessa et al. (2023b).[1]

Winter (1994) demonstrated that this mechanism has a unique subgame perfect equilibrium, which assigns equal probabilities according to the principle of indifference. At this equilibrium, the grand coalition forms, and the *a priori* expected equilibrium payoff aligns with the Shapley value.

Hart and Mas-Colell (1996) introduced a bargaining procedure designed for monotonic cooperative games, which is a less stringent condition compared to the strict convexity required by Winter mechanism. In the following, we present the simplified version of the mechanism, as implemented in Chessa et al. (2023b). In this mechanism, the bargaining process begins with a randomly selected proposer making an offer to the other players, framed as, "If you wish to form a coalition with me, I will give you..." The other players, acting sequentially, may choose to either accept or reject the offer. Unanimity is required for the proposal to be accepted. A critical aspect of the model is determining what happens if no agreement is reached, leading the game to progress to the next stage. The more general mechanism proposed by Hart and Mas-Colell al-

[1] Chessa et al. (2023a) compared a one-period implementation and a two-period implementation of the Winter mechanism, investigating scenarios with both low and high delay costs in the latter case. Their findings indicate that the three different implementations yield similar outcomes in terms of coalition formation, alignment with the Shapley value predictions, and satisfaction of the axioms.

Table 1: A three-player game

S	1	2	3	1,2	1,3	2,3	N
$v(S)$	10	20	20	50	50	60	100

lows the proposer, even after a rejection, to remain in the game and continue to the next stage with a certain probability. In our analysis, we consider the special case where this probability is zero. If the proposal is rejected, the proposer exits the game with her individual value, and bargaining continues among the remaining players, with a new proposer randomly selected.

Hart and Mas-Colell (1996) demonstrated that this game has a unique subgame perfect equilibrium. At this equilibrium, the grand coalition forms, and the *a priori* expected equilibrium payoff corresponds to the Shapley value.

We illustrate the two mechanisms using the strictly convex three-player game presented in Table 1.

As previously mentioned, the convexity assumption implies monotonicity. Therefore, this game satisfies the conditions required by both the Winter and H-MC mechanisms. The Shapley value for this game is represented by the vector $\phi(v) = \left(\frac{80}{3}, \frac{110}{3}, \frac{110}{3}\right) \approx (26.67, 36.67, 36.67)$, which corresponds to the *a priori* equilibrium payoff for both mechanisms.

Now, let us assume that player 1 is randomly selected as the first proposer in both mechanisms. Regardless of the subsequent order of players in the Winter mechanism, the proposer will receive an *a posteriori* equilibrium payoff of 40 in both mechanisms, which equals their marginal contribution to the grand coalition, i.e., $v(N) - v(N \setminus \{1\})$. Suppose further that the order of players in the Winter mechanism is 1, 2, and 3. In this

Table 2: The games

S	1	2	3	4	1,2	1,3	1,4	2,3	2,4	3,4	1,2,3	1,2,4	1,3,4	2,3,4	N
$v_1(S)$	0	5	5	10	20	20	25	20	25	25	50	60	60	60	100
$v_2(S)$	0	20	20	30	20	20	30	45	55	60	45	55	60	100	100
$v_3(S)$									$= v_1(S) + v_2(S)$						
$v_4(S)$									$= 2v_1(S)$						

case, the *a posteriori* equilibrium payoff for the Winter mechanism is given by the vector $(40, 40, 20)$, where player 2 demands his/her marginal contribution $v(\{2, 3\}) - v(\{3\})$, and player 3 claims his/her individual value $v(\{3\})$. Conversely, in the case of the H-MC mechanism, the proposer offers the Shapley value of the reduced game to players 2 and 3. Consequently, the *a posteriori* equilibrium payoff is given by the vector $(40, 30, 30)$.

3 The experimental design

We first describe the 4-player bargaining games we consider in our experiment. We then explain our four treatments.

3.1 The games

We consider the four 4-player games shown in Table 2. These games are the same as those considered in Chessa et al. (2022, 2023a,b). This is to allow a direct comparison of the results. The Shapley values of the four games is presented in Table 3. The Equal Division solution is simply equal to $ED(v_k) = (25, 25, 25, 25)$ when $k = 1, 2$, and $ED(v_k) = (50, 50, 50, 50)$ when $k = 3, 4$.

Following Chessa et al. (2022, 2023a,b), in our experiment, each participants played

Table 3: The Shapley value of games 1, 2, 3 and 4

	$\phi_1(v)$	$\phi_2(v)$	$\phi_3(v)$	$\phi_4(v)$
Game 1	22.08	23.75	23.75	30,42
Game 2	0	28.33	30.83	40.83
Game 3	22.08	52.08	54.58	71.25
Game 4	44.16	47.5	47.5	60.83

all four games twice. The order of games was counter balanced across sessions. Namely, participants played these four games in one of the following four orderings: 1234, 2143, 3412, and 4321. At the beginning of a new round (i.e., new play of a game), participants were randomly rematched into groups of four players, and their roles were randomly reassigned within a newly created group.[2]

3.2 Treatments

In our 2×2 between subjects design, we vary (a) whether or not participants communicate freely via online chat during the negotiation, and (b) whether the negotiation is offer-based or demand-based.

In the treatments with free-form communication, participants could freely send chat messages (except for those messages that can identify oneself and those ones that can insult others). Messages could be seen by everyone in the same group, and they could be sent anytime during a play of a game (or a negotiation).

In all the treatments, the maximum duration of a negotiation was randomly deter-

[2]The reasons for these design chocies given in Chessa et al. (2023b) are as follow. While letting participants play all four games, instead of just one, in each session as well as randomly reassigning their roles across rounds instead of fixing it might slow down their learning how to play the game, (a) having within-session variations was needed for some of the analyses to choose the within session variation of the games, and (b) random reassingment was implemented to avoid upsetting participants because of the existence of the null player in one of the four games.

mined between 300 and 360 seconds. Participants were informed that a negotiation could continue for at least 300 seconds, but its end would have been terminated at a randomly chosen moment during the following 60 seconds. The negotiation could end earlier, when the grand coalition was formed, or when only one player remained without belonging to any coalition. We now describe the difference between our offer-based and demand-based negotiation protocol in detail.

3.3 Offer-based protocol

This protocol is similar to the one that Shinoda and Funaki (2019) call "unstructured bargaining" protocol. Namely, at any time during a negotiation, each player is free to propose or to approve a coalition that include him/herself among players who remain in the game and an associated allocation within the coalition. Below, let proposing or approving a coalition mean both proposing or approving members of a coalition and the associated allocation among them. For example, at the beginning of a negotiation when all the four players remain in the game, player 1 can propose either {1,2}, {1,3}, {1,4}, {1,2,3}, {1,2,4}, {1,3,4}, or {1,2,3,4}. Note that single player coalition is not considered here as, we explain later, it is the default outcome for the player when s/he ends the game without belonging to any coalition. Instead of proposing a coalition, a player can also approve a coalition, that includes him/herself, proposed by another player.

In our experiment, each player can propose or approve at most one coalition at any point in time. Thus, if a player has proposed a coalition but would like to approve the one proposed by another player, first the player has to withdraw his/her proposal. Similarly, if a player has approved a coalition proposed by another player but would like to propose a new one, the player has to first withdraw his/her approval.

If all the members of a proposed coalition approve it, the coalition is formed and its members all exit the negotiation and receive the allocated points. The negotiation continues with remaining players. If there remains only one player, the negotiation ends. The players without an agreed coalition at the end of the negotiation (either because of the time limit or because s/he is the only player left) obtain their individual value.

3.4 Demand-based protocol

In this protocol, at any point during a negotiation, players are free to demand points they want to obtain. Note that, unlike the offer-based protocol, in doing so, players are not proposing a coalition. Instead, they are expressing the points they want to receive for them to join a coalition. Each player can make at most one demand at any time during the negotiation. Players are free to modify their demands anytime during a negotiation.

A coalition can be formed if the sum of the demands made by its members is no greater than its worth. When there is such a coalition for a player, the player is free to agree to form it. Just as in the offer-based protocol, we exclude a single player coalition here, because it is the default outcome for the player when s/he ends the game without belonging to any coalition. Each player can agree to form at most one coalition at any time during the negotiation. Thus, if players want to form a different coalition than the one s/he is currently agreeing to form, they need to withdraw the current agreement before agreeing to form a new coalition.

A coalition is formed if all its members agree to form it. Once a coalition is formed, its members exit the negotiation and receive the points they have demanded. Just as in the offer-based protocol, the negotiation continues with remaining players. If there remains only one player, the negotiation ends. The players without an agreed coalition at the end of the negotiation (either because of the time limit or because s/he is the only player left) obtain his/her singleton value.

4 Results

The experiment was conducted at the Institute of Social and Economic Research (ISER), Osaka University, in May and June 2021 (offer-based) and May and June 2022 (demand-based). A total of 344 students, who have never participated in similar experiments before, were recruited as subjects of the experiment. See Table 4 for the number of participants as well as mean duration and mean payment in each treatment. The experiment was computerized with z-Tree (Fischbacher, 2007) and participants were recruited using ORSEE (Greiner, 2015).

At the end of the experiment, two rounds (one from the first four rounds and another from the last four rounds) were randomly selected for payments. Participants received cash reward based on the point they have earned in these two selected rounds with an exchange rate of 20 JPY = 1 points in addition to 1500 JPY participation fee. The experiment lasted on average around 90 minutes including the instruction, comprehension quiz, and payment. Participants received a copy of instruction slides, and a pre-recorded instruction video was played. Quiz was given on the computer screen after the explanation of the game. The user interface was explained during the practice rounds referring to the handout about the computer screen. See Appendix A for English translations of the instruction materials and the comprehension quiz.

Table 5 summarizes the duration of a negotiation, the frequency of complete break down (no coalition being formed), the number of proposals/demands made within a

Table 4: The number of participants, the mean duration, and the mean payment in four semi-structured treatments and Winter and H-MC from Chessa et al. (2023b).

Treatment	No. of Participants	Mean Duration	Mean payment	When
Demand-based Without chat (No chat)	88 (24x2 + 20x2)	1h34m	2810 JPY	May-June 2022
Demand-based With chat (chat)	84 (24x2,16,20)	1h22m	2860 JPY	May-June 2022
Offer-based Without chat (No chat)	88 (24x2 + 20x2)	1h36m	2810 JPY	June-July 2021
Offer-based With chat (chat)	84 (20x3 + 24x1)	1h36m	2900 JPY	June-July 2021
Winter	96 (24x4)	1h40m	2650 JPY	Jan - Feb. 2019
H-MC	80 (24, 20x2, 16)	1h45m	2850 JPY	Jan - Feb. 2022

negotiation, and the number of messages sent during a negotiation (in treatments with chat), and the time until the first coalition being formed in the semi-structured experiments.[3]

The average duration of a negotiation is significantly longer in the offer-based than in the demand-based protocols.[4] The possibility of chat does not significantly affect the duration of the negotiation.[5] Note that while more messages are sent under the

[3]The table is created based on the estimated coefficients of the following linear regressions: $y_i = \beta_1 ONC_i + \beta_2 OC_i + \beta_3 DNC_i + \beta_4 DC_i + \mu_i$ where y_i is the statistics of interest in group i, ONC_i, OC_i, DNC_i, and DC_i are dummy variables that take value 1 if the treatment is offer-based no chat (ONC), offer-based with chat (OC), demand-based no chat (DNC), and demand-based with chat (DC), respectively, and zero otherwise. The standard errors are corrected for within session clustering effect. The statistical tests are based on the Wald test for the equality of the estimated coefficients of treatment dummies.

[4]$p = 0.0069$ and $p < 0.0001$ for without chat and with chat, respectively. Wald test.

[5]$p = 0.207$ and $p = 0.975$ for the demand-based and the offer-based protocols, respectively. Wald test.

Table 5: Summary statistics of semi-structured bargaining

Treatment	The duration[1]	The frequency of complete failure	The number of Proposals or demands[1]	The number of Messages[2]	The number of non-greeting Messages	The duration[3]	The time until the formation of the first coalition[3]
Demand-based	119.27	0.045	7.95			109.82	97.75
Without chat (No chat)	(14.58)	(0.029)	(0.33)			(9.74)	(6.25)
Demand-based	96.92	0.018	6.31	2.03	1.69	92.61	80.50
With chat (chat)	(8.63)	(0.010)	(0.33)	(0.69)	(0.71)	(9.02)	(11.46)
Offer-based	177.05	0.131	4.88			154.41	152.55
Without chat (No chat)	(11.33)	(0.013)	(0.24)			(11.02)	(11.47)
Offer-based	177.56	0.119	3.33	4.68	3.16	157.89	156.23
With chat (chat)	(11.34)	(0.023)	(0.13)	(1.33)	(0.62)	(13.57)	(13.97)
Num. Obs.	688	688	688	336	336	634	634
R^2	0.671	0.265	0.773	0.403	0.312	0.653	0.657

Note: Standard errors are corrected for session-level clustering effects and shown in parentheses.
1: Include those gruops that did not form any coalition (thus terminated by reaching the maximum duration)
2: Include greeting messages.
3: Do not include those gruops that did not form any coalition.

offer-based than the demand-based protocol when chat is possible, the difference is not statistically significant.[6] The complete failure of the negotiation is more frequently observed under the offer-based than the demand-based protocols,[7] and the possibility of chat does not significantly affect the failure rate.[8]

The longer duration of a negotiation under the offer-based protocol is not just because there are more groups in which negotiation failed completely. Even among those groups where a coalition has been formed, the negotiation took longer under the offer-based than the demand-based protocols.[9] The same is true for the time it has taken before the first coalition being formed.[10]

The number of proposals made under the offer-based protocols is significantly smaller than the number of demands made under the demand-based protocols.[11] The possibility of chat significantly reduces the number of proposals or the demands made.[12] Both the number of demands and the proposals made are, however, large compared to what have been allowed in Winter and H–MC (maximum is 4) considered in Chessa et al. (2023b). One may expect that this difference in the number of demands or proposals made between the structured and semi-structured procedures would affect the outcomes. We now turn to analyzing the outcomes of the negotiation.

[6] $p = 0.1200$ and $p = 0.1619$ with and without greeting messages, respectively. Wald test.

[7] $p = 0.0166$ and $p = 0.0013$ for without chat and with chat, respectively. Wald test.

[8] $p = 0.3834$ and $p = 0.6701$ for the demand-based and the offer-based protocols, respectively. Wald test.

[9] $p = 0.0084$ and $p = 0.0011$ for without chat and with chat, respectively. Wald test.

[10] $p = 0.0008$ and $p = 0.0008$ for without chat and with chat, respectively. Wald test.

[11] $p < 0.0001$ and $p < 0.0001$ for without chat and with chat, respectively. Wald test.

[12] $p = 0.0030$ and $p = 0.0001$ for the demand-based and the offer-based protocols, respectively. Wald test.

4.1 Grand coalition formation and efficiency

For our four games, the structured mechanisms (namely, a simplified version of the demand-based Winter mechanism (Winter, 1994) and a simplified version of the offer-based Hart and MasColell (H–MC) mechanism (Hart and Mas-Colell, 1996), as presented in Section 2.2) theoretically predict that the grand coalition will form, and that full efficiency will be reached. Then, we first compare the frequency of cooperation and the level of efficiency across our four semi-structured mechanisms treatments, and then we compare these outcomes with the results from the experiments on the structured bargaining mechanisms reported in Chessa et al. (2023b).

Table 6 shows the frequencies of various coalitions being formed, focusing on the grand coalition and coalitions with three members. Our analysis thus centers on those groups that reached full cooperation, or those groups that did not succeed in doing that, but that have shown a high level of cooperation. As one can observe, on the one hand, in games 1, 3 and 4, the grand coalition is the most frequently formed under semi-structured procedures regardless of whether it is demand-based or offer-based, and with or without chat. It is also the case under structured Winter and H–MC mechanisms, except for Winter mechanism in game 3 where the coalition $\{2, 3, 4\}$ is the most frequently formed coalition. In game 2, on the other hand, instead of the grand coalition, the three player coalition that excludes the null player $\{2, 3, 4\}$ is the most frequently formed coalition except under the H–MC mechanism. Chessa et al. (2023b) noted that the proposers do not exclude the null player in game 2 to avoid the risk of the proposal being rejected and receiving a singleton payoff under H–MC. This result shows that such a risk imposed by an offer-based structured mechanism is eliminated under the offer-based semi-structured procedures.

Table 6: Frequencies of coalitions being formed

Game 1

	Demand based			Offer based		
Coalition	No Chat	Chat	Winter	No Chat	Chat	H-MC
{1234}	38	34	23	34	39	25
{234},{1}	1	1	2	1	0	3
{134},{2}	1	1	10	0	0	4
{124},{3}	0	2	8	2	0	4
{123},{4}	1	0	0	1	0	2
others	3	4	5	6	3	2
total	44	42	48	44	42	40

Game 2

	Demand based			Offer based		
Coalition	No Chat	Chat	Winter	No Chat	Chat	H-MC
{1234}	3	5	0	3	9	18
{234},{1}	33	28	27	27	20	7
{134},{2}	0	1	0	0	0	1
{124},{3}	0	0	0	0	0	1
{123},{4}	0	0	0	0	0	0
others	8	9	21	14	13	13
total	44	42	48	44	42	40

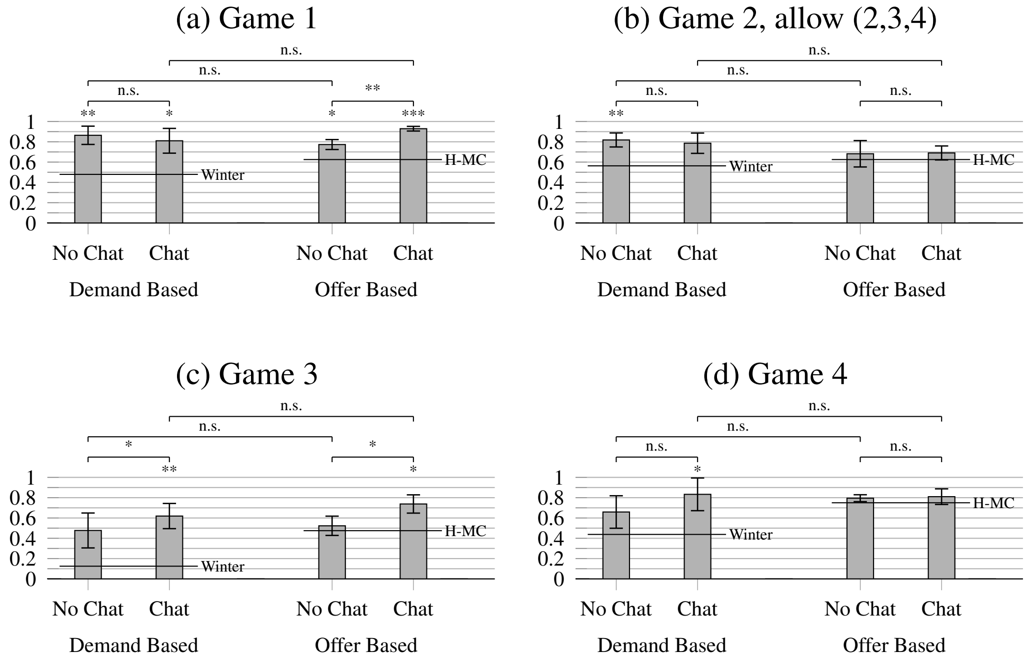
Game 3

	Demand based			Offer based		
Coalition	No Chat	Chat	Winter	No Chat	Chat	H-MC
{1234}	21	26	6	23	31	19
{234},{1}	10	8	27	14	9	5
{134},{2}	3	1	4	0	1	3
{124},{3}	3	1	1	0	0	3
{123},{4}	0	0	2	1	0	1
others	7	6	8	6	1	9
total	44	42	48	44	42	40

Game 4

	Demand based			Offer based		
Coalition	No Chat	Chat	Winter	No Chat	Chat	H-MC
{1234}	29	35	21	35	34	30
{234},{1}	4	2	4	0	1	1
{134},{2}	3	1	7	2	0	2
{124},{3}	0	2	6	0	0	2
{123},{4}	4	2	5	0	0	0
others	4	0	5	7	7	5
total	44	42	48	44	42	40

Figure 1: Proportion of times the grand coalition formed.



Note: Error bars show one standard error range. ***, **, and * indicates the proportion of times the grand coalition formed being significantly different between two treatments at 1%, 5%, and 10% significance level, respectively (Wald test). The "n.s." indicate the absence of significant difference at 10% level between the two treatments compared.

In Figure 1, we show graphically the result of comparisons across treatments of the frequencies of the grand coalition formation. To take into account the existence of the null player, we include the three player coalition without the null player in game 2 ({2,3,4}) as a grand coalition. The horizontal line with indication of Winter and H–MC are the experimental results of these two structured procedures reported in Chessa et al. (2023b).[13]

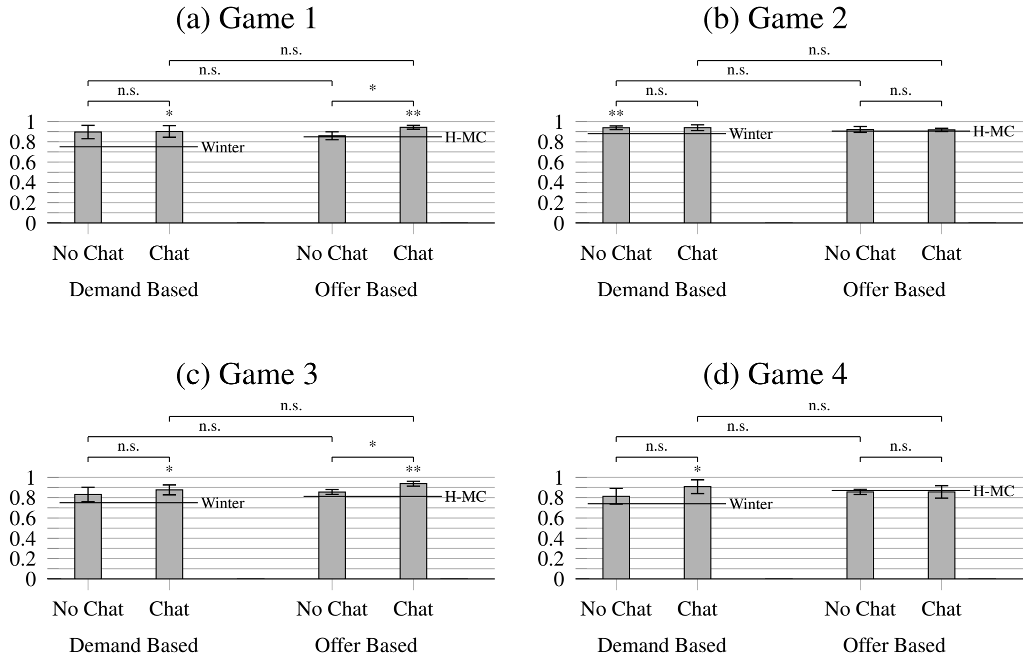
[13]The figure is created based on the estimated coefficients of the following linear regressions: $y_i = \beta_1 ONC_i + \beta_2 OC_i + \beta_3 DNC_i + \beta_4 DC_i + \beta_5 Winter_i + \beta_6 H - MC_i + \mu_i$ where y_i is a dummy variable that takes the value 1 if the grand coalition is formed, and zero otherwise, in group i, for the grand coalition formation, $Winter_i$, and $H - MC_i$ are dummy variables that take value 1 if the treatment is winter, and H–MC, respectively, and zero otherwise. Other treatment dummies are the same as the one explained above. The standard errors are corrected for within session clustering effect. The statistical tests are based on the Wald test for the equality of the estimated coefficients of treatment dummies.

We observe that the grand coalition is formed more frequently under the semi-structured procedure than under the structured procedure, both for the demand-based and the offer-based procedures regardless of the existence of chat in game 1, and when chat is allowed for game 3. In games 2 and 4, there is no significant difference between the semi-structured and structured offer-based procedure. For the demand-based procedures, the grand coalition is more frequently formed under the semi-structured ones than structured one, and significantly so when chat is not allowed in game 2 and when chat is allowed in game 4. Among semi-structured procedures, there are cases where chat significantly facilitates the formation of the grand coalition (game 1 for the offer-based and game 3 for the demand-based procedure). Conditionnal on whether the freefrom chat is possible or not, we do not observe significant difference between the demand-based and the offer-based semi-structured procedures in none of the four games.

Figure 2 shows the efficiency across treatments in each game. The efficiency is defined as the share of the sum of the points obtained by four players relative to the worth of the grand coalition.[14] Because the efficiency is higher when the grand coalition is formed more frequently, the results are similar to the frequencies of the grand coalition formation we have discussed above. However, it is important to notice that even when the grand coalition is formed, the resulting share can still be inefficient. Thus, this additional analysis is of interest. In our results, efficiency is significantly higher, both for the demand-based and the offer-based, under semi-structured procedure with chat than structured procedure in games 1 and 3. For games 2 and 4, while the efficiency is not significantly different between structured and semi-structured offer-based procedures, in case of the demand-based procedure, it is higher under semi-structured than

[14]The figure is created based on the estimated coefficients of the linear regressions similar to the frequencies of the grand coalition formation except the dependent variable is now the efficiency.

Figure 2: Efficiency



Note: Error bars show one standard error range. ***, **, and * indicates the proportion of times the grand coalition formed being significantly different between two treatments at 1%, 5%, and 10% significance level, respectively (Wald test). The "n.s." indicate the absence of significant difference at 10% level between the two treatments compared.

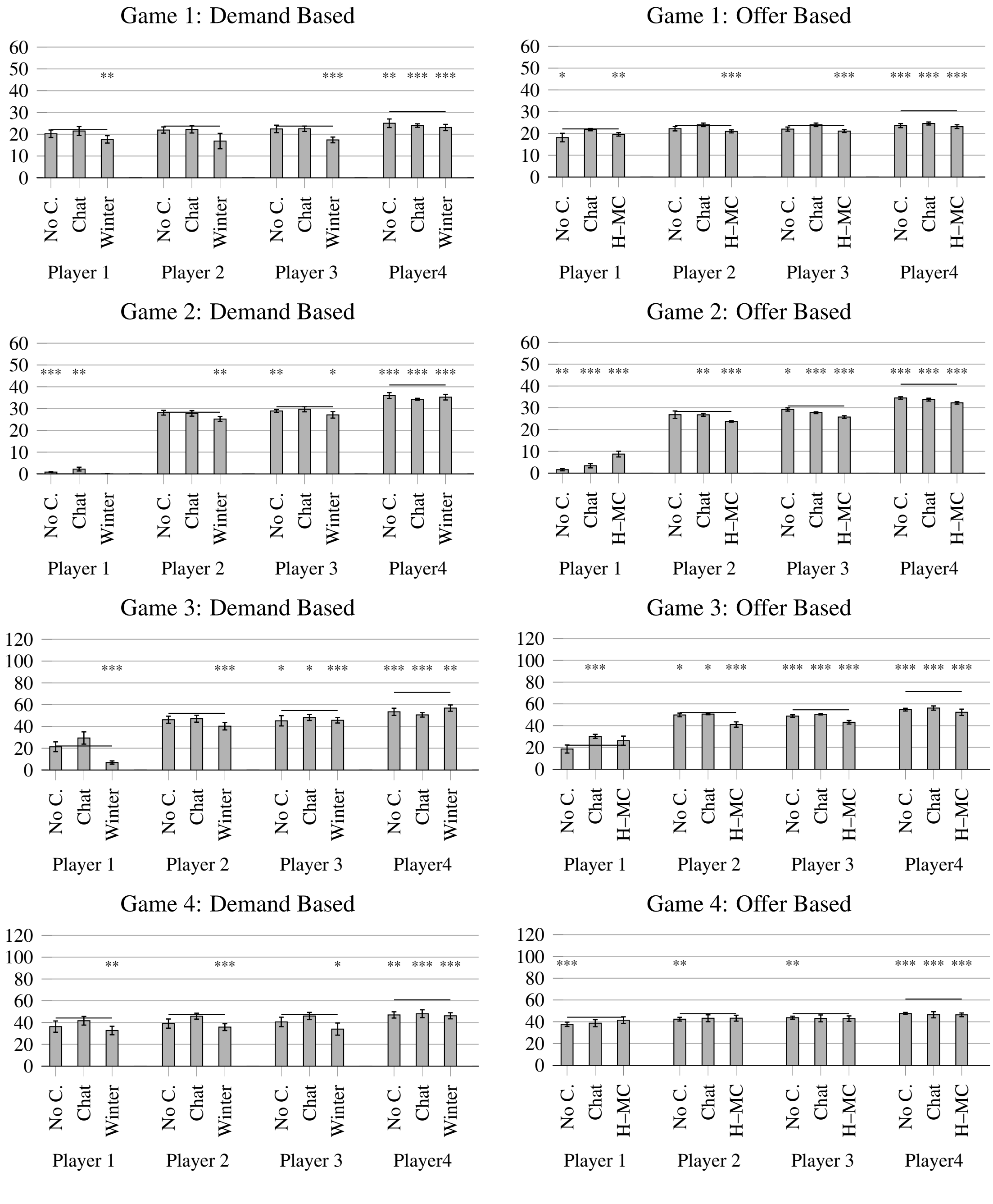
the structured procedure (without chat in game 2 and with chat in game 4).

4.2 Allocations

In the previous section, we examined our allocation payoffs from the perspective of the resulting social welfare. Now, we turn our attention to an individual-level analysis, i.e., investigating the results of each player, depending on his/her role in the games.

Figure 3 shows the mean payoffs for each player in the four games. Treatments are divided into those demand-based (without chat (No C.), with chat (chat), and Winter) and those offer-based (without chat (No C.), with chat (chat), and H–MC). The horizon-

Figure 3: Mean payoffs for each player in each treatment



Note: the horizontal lines indicate the Shapley values. Error bars show one standard error range. ***, **, and * indicate the average payoff being significantly different from the Shapley value at 1, 5, and 10 % significance level (Wald test).

tal lines indicate the Shapley values for each player in each game. The mean and the standard errors are obtained by running a set of ordinary least squares (OLS) regressions for the following system of equations for each treatment separately:

$$\begin{aligned}
\pi_1 &= a_1 g_1 + a_2 g_2 + a_3 g_3 + a_4 g_4 + u_1 \\
\pi_2 &= b_1 g_1 + b_2 g_2 + b_3 g_3 + b_4 g_4 + u_2 \\
\pi_3 &= c_1 g_1 + c_2 g_2 + c_3 g_3 + c_4 g_4 + u_3 \\
\pi_4 &= d_1 g_1 + d_2 g_2 + d_3 g_3 + d_4 g_4 + u_4
\end{aligned} \tag{1}$$

where π_i is the payoff of player i, g_j is a dummy variable that takes a value of 1 if the game $j \in \{1, 2, 3, 4\}$ is played, and zero otherwise. Because participants play all four games twice, we correct the standard errors for within-group clustering effects. Note that the estimated coefficients a_j, b_j, c_j, and d_j are the average payoffs in game j for players 1, 2, 3, and 4, respectively.

We observe that mean payoff of player 4 is significantly lower than the Shapley value, at at least 5% significance level, in all the games and all the treatments. In terms of treatment differences, we observe that the average payoffs tend to be lower under Winter and H–MC than the corresponding semi-structured ones. As a result, the average payoffs deviate significantly from the Shapley values for more players in more games under the structured than under the semi-structured procedure.

Furthermore, there is a notable difference in terms of the average payoff of the null player, i.e., player 1 in game 2, between the structured and semi-structured procedures. On one hand, in Winter, the average payoff of the null player was zero and equal to the Shapley value. On the other hand, in H–MC, the average payoff of the null player is much higher. The average payoffs of the null player under the semi-structured experiments are between Winter and H–MC, and is higher when chat is possible. As we will see next, the null player property tend to fail by a larger extent under the offer-based experiment than under the demand-based experiment regardless of whether it is structured (Winter vs H–MC as shown by Chessa et al., 2023b) or semi-structured, although the difference is smaller in the latter. We now investigate the sources of the deviation of the realized allocation of the Shapley value.

We observe that both the higher average payoff for the null player (the one with a zero Shapley value) and the generally lower payoff for the fourth player (the one with the highest Shapley value) align with the observable tendency towards an equal distribution of shares. This matter, largely documented in the literature, will be further discussed in Section 4.4.

4.3 Shapley distance

To understand in greater detail why the realized allocations diverge so significantly from the Shapley value prediction, we apply the approach of Aguiar et al. (2018) to decompose the deviation[15] into the failure of efficiency, symmetry, additivity, and null player property.[16] The same method of decomposition is used in Chessa et al. (2022, 2023a,b) in their experiments on structured mechanisms. Although the procedure of the decomposition is presented in these previous papers, in order for this paper to be self-contained, we re-present it here.

Let π be the realized allocation (i.e., vector of payoffs) in a game. First, we find an allocation, π^{sym}, that satisfies the symmetry and is closest to π. We do so by summing

[15] Rapoport (1987) considers alternative metrics to measure the distance between payoff vectors and solution concepts such as the Bonacich's error measure (Bonacich, 1979) and the net rate of success (Selten and Krischker, 1983).

[16] Aguiar et al. (2018) decompose the deviation into the failure of efficiency, symmetry, and marginality. While these three components are orthogonal to each other, in our decomposition, the failure due to additivity and null player property are not orthogonal.

the payoffs obtained by symmetric players s (players 2 and 3 in games 1 and 4) and divide it equally among them. That is, in games 1 and 4, $\pi_s^{sym} = \sum_{s\in\{2,3\}} \pi_s/2$. For other players k, $\pi_k^{sym} = \pi_k$.

Second, we find a new allocation, $\pi^{sym,eff}$, that satisfies efficiency and is closest to π^{sym}. For each player $i = 1, 2, 3, 4$, $\pi_i^{sym,eff} = \pi_i^{sym} + [v(N) - \sum_{j\in N} \pi_j]/4$.

Third, we find yet another allocation, $\pi^{sym,eff,null}$, that satisfies null player property and is closest to $\pi^{sym,eff}$. For a null player n (player 1 in game 2), $\pi_n^{sym,eff,null} = 0$. And for other players j in the game, $\pi_j^{sym,eff,null} = \pi_j^{sym,eff} + \pi_n^{sym,eff}/3$. That is, three other players in the game equally share $\pi_n^{sym,eff}$ of the null player. If there is no null player, $\pi_i^{sym,eff,null} = \pi_i^{sym,eff}$ for all i.

Let $e_i^{sym} = \pi_i - \pi_i^{sym}$, $e_i^{eff} = \pi_i^{sym} - \pi_i^{sym,eff}$, $e_i^{null} = \pi_i^{sym,eff} - \pi_i^{sym,eff,null}$, and $e_i^{add} = \pi_i^{sym,eff,null} - \phi_i(v)$ for all i.

Aguiar et al. (2018, Theorem 3) shows that an allocation π from game v can be decomposed as $\pi = \phi(v) + e^{sym} + e^{eff} + e^{null} + e^{add}$. Therefore, the Shapley error, $e^{\phi} = \pi - \phi(v)$, is $e^{\phi} = e^{sym} + e^{eff} + e^{null} + e^{add}$, and the Shapley distance, $||e^{\phi}||^2$, can be decomposed into

$$||e^{\phi}||^2 = ||e^{sym}||^2 + ||e^{eff}||^2 + ||e^{null}||^2 + ||e^{add}||^2 + 2 < e^{add}, e^{null} >$$

where $< \cdot, \cdot >$ is the scalar product and for any vector $y \in \mathbb{R}^n$, $||y||^2 =< y, y >= \sum_{i\in N} y_i^2$. As noted above, in general, vectors e^{null} and e^{add} are not orthogonal so that $< e^{add}, e^{null} >$ is not equal to zero. Its magnitude, however, is much smaller than the remaining components in our experimental data.

We perform the Shapley distance decomposition of each realized allocation and the corresponding Shapley value, and compute the average distance, pooling data of all

Table 7: Result of Shapley distance decomposition. Based on pooling the data of all groups and all games

	$\|\|e^{sym}\|\|^2$	$\|\|e^{eff}\|\|^2$	$\|\|e^{null}\|\|^2$	$\|\|e^{add}\|\|^2$	$\|\|e^{\phi}\|\|^2$
Demand-Based	16.03	448.09	7.03	216.50	687.59
No chat	(5.29)	(127.33)	(1.37)	(20.29)	(145.27)
Demand-Based	10.53	241.08	19.45	281.07	552.09
With chat	(4.96)	(76.67)	(6.34)	(28.56)	(98.00)
Offer-Based	7.98	478.02	13.49	164.30	663.74
No chat	(1.78)	(74.28)	(2.73)	(11.71)	(64.54)
Offer-Based	0.07	363.13	25.64	211.55	600.37
With chat	(0.07)	(119.73)	(6.94)	(13.49)	(115.54)
Winter	85.18	606.81	7.28	321.49	1020.68
	(18.55)	(99.11)	(1.83)	(14.95)	(70.63)
H–MC	38.19	429.96	63.97	270.84	802.88
	(12.45)	(52.23)	(8.08)	(20.25)	(61.32)
No. Obs	1040	1040	1040	1040	1040
R^2	0.121	0.146	0.079	0.343	0.300
p-value*	0.0047	0.0068	0.0000	0.0000	0.0007

Note: Standard errors are corrected for session-level clustering effects and shown in parentheses. $< e^{add}, e^{null} >$ are not reported in the table as they are negligible (the mean values are 0.0020, 0.0031, 0.0039, 0.0046, 0.0026, 0.0093 for demand-based no chat, demand-based with chat, offer-based no chat, offer-based with chat, Winter, and H–MC, respectively.).
*: The null hypothesis is the estimated coefficients of four treatment dummies (excluding Winter and H–MC) are the same (Wald test).

groups and all games, to compare across four treatments by regressing each of them onto four treatment dummies (without constant).[17] Results of the regressions are presented in Table 7.

Column $||e^{\phi}||^2$ of Table 7 shows that the Shapley distance is lower under the semi-

[17]Namely, we run the following regressions $||e_i||^2 = \beta_1 ONC_i + \beta_2 OC_i + \beta_3 DNC_i + \beta_4 DC_i + \beta_5 Winter_i + \beta_6 H - MC_i + \mu_i$ where $||e_i||^2$ is the decomposed distance in group i, ONC_i, OC_i, DNC_i, DC_i, $Winter_i$, $H - MC_i$ are dummy variables that take value 1 if the treatment is offer based no chat (ONC), offer based with chat (OC), demand based no chat (DNC), demand based with chat (DC), Winter, and H–MC, respectively, and zero otherwise. The standard errors are corrected for within session clustering effect. The statistical tests are based on the Wald test for the equality of the estimated coefficients of treatment dummies.

Table 8: p-values for pair-wise comparisons

$||e^{sym}||^2$

Test	p-value
Demand, No Chat vs Demand, With Chat	0.323
Offer, No Chat vs Offer, With Chat	0.867
Demand, No Chat vs Offer, No Chat	0.361
Demand, With Chat vs Offer, With Chat	0.859
Demand, No Chat vs Winter	0.220
Demand, With Chat vs Winter	0.041**
Offer, No Chat vs H–MC	0.552
Offer, With Chat vs H–MC	0.550

$||e^{eff}||^2$

Test	p-value
Demand, No Chat vs Demand, With Chat	0.131
Offer, No Chat vs Offer, With Chat	0.441
Demand, No Chat vs Offer, No Chat	0.859
Demand, With Chat vs Offer, With Chat	0.309
Demand, No Chat vs Winter	0.346
Demand, With Chat vs Winter	0.014**
Offer, No Chat vs H–MC	0.607
Offer, With Chat vs H–MC	0.619

$||e^{null}||^2$

Test	p-value
Demand, No Chat vs Demand, With Chat	0.135
Offer, No Chat vs Offer, With Chat	0.078*
Demand, No Chat vs Offer, No Chat	0.003***
Demand, With Chat vs Offer, With Chat	0.637
Demand, No Chat vs Winter	0.913
Demand, With Chat vs Winter	0.092*
Offer, No Chat vs H–MC	0.0001***
Offer, With Chat vs H–MC	0.0042***

$||e^{add}||^2$

Test	p-value
Demand, No Chat vs Demand, With Chat	0.102
Offer, No Chat vs Offer, With Chat	0.063*
Demand, No Chat vs Offer, No Chat	0.035**
Demand, With Chat vs Offer, With Chat	0.107
Demand, No Chat vs Winter	0.0022***
Demand, With Chat vs Winter	0.249
Offer, No Chat vs H–MC	0.0008***
Offer, With Chat vs H–MC	0.0330**

$||e^{\phi}||^2$

Test	p-value
Demand, No Chat vs Demand, With Chat	0.364
Offer, No Chat vs Offer, With Chat	0.627
Demand, No Chat vs Offer, No Chat	0.891
Demand, With Chat vs Offer, With Chat	0.699
Demand, No Chat vs Winter	0.064*
Demand, With Chat vs Winter	0.0026***
Offer, No Chat vs H–MC	0.146
Offer, With Chat vs H–MC	0.150

structured bargaining than Winter or H–MC. As one can observe from Table 8, however, among these differences between semi-structured and structured procedures, the difference between the demand-based and Winter is only marginally statistically significant (at 5% level and 10% level for with chat vs Winter and without chat vs Winter, respectively). Tables 7 and 8 further shows that this significant difference of $||e^{\phi}||^2$ between the demand-based with chat and Winter is due to the significant difference in $||e^{sym}||^2$ and $||e^{eff}||^2$, and the difference between the demand-based without chat and Winter is due to the difference in $||e^{add}||^2$.

Other significant differences between semi-structured experiments and structured ones are $||e^{null}||^2$ and $||e^{add}||^2$ between offer-based protocol (with and without chat) and H–MC. As we have seen in Figure 3, the average payoffs of the null player was particularly high in H–MC, compared to the other treatments. Chessa et al. (2023b) conjectured this to be caused by proposers trying to avoid their proposal to be rejected by the null player. Indeed, in the version of H–MC considered in Chessa et al. (2023b), it was not possible for the proposer to propose a coalition excluding the null player unless the null player has been removed from the game already. In the semi-structured offer-based protocol, it is possible for non-null players to propose such a coalition without fear of the null player rejecting it. The possibility of chat makes is more likely for the null player property to be violated both under the demand-based and the offer-based protocols although the differences, from the treatment without chat, are not statistically significant.[18]

[18] In the same vein,Kahan and Rapoport (1980b) demonstrated that the presence or absence of messages (conditions R and N in their paper, respectively) affects their discrepancy score index from the bargaining sets defined as the mean absolute deviation of each player's payoff in a winning coalition from his quota.

Table 9: Eight allocation types

Type	Example	Description
1: Eff, Equal, WCR	{25,25,25,25} in game 1	$\sum_i \pi_i = v(N)$, $\pi_i = \pi_j$ for all $i, j \in GC$, WCR
2: Eff, Not Equal, WCR	{0,33,33,34} in game 2	$\sum_i \pi_i = v(N)$, $\pi_i \neq \pi_j$ for some $i, j \in GC$, WCR
3: Eff, Equal, Not WCR	{25,25,25,25} in game 2	$\sum_i \pi_i = v(N)$, $\pi_i = \pi_j$ for all $i, j \in GC$, Not WCR
4: Eff, Not Equal, Not WCR	{1,33,33,33} in game 2	$\sum_i \pi_i = v(N)$, $\pi_i \neq \pi_j$ for some $i, j \in GC$, Not WCR
5: Not Eff, Equal, WCR	{24,24,24,24} in game 1	$\sum_i \pi_i < v(N)$, $\pi_i = \pi_j$ for all $i, j \in GC$, WCR
6: Not Eff, Not Equal, WCR	{15,15,20,30} in game 1	$\sum_i \pi_i < v(N)$, $\pi_i \neq \pi_j$ for some $i, j \in GC$, WCR
7: Not Eff, Equal, Not WCR	{0,33,33,33} in game 2	$\sum_i \pi_i < v(N)$, $\pi_i = \pi_j$ for all $i, j \in GC$, Not WCR
8: Not Eff, Not Equal, Not WCR	{0,30,30,35} in game 2	$\sum_i \pi_i < v(N)$, $\pi_i \neq \pi_j$ for some $i, j \in GC$, Not WCR

Note: WCR stands for satisfying the weak coalitional rationality. GC stands for the grand coalition.

4.4 The realized allocations within the grand coalition

In the final part of this results session, we investigate the realized allocations within the grand coalition (including {2,3,4} in game 2), to better understand the previous results. We focus on grand coalition because it is important to stress that potential differences with the theoretical prediction are not only the consequence of failing to form the grand coalition, but also on the final allocations even when players manage to form it.

We categorize various allocations into eight types, summarized with examples in Table 9, depending on whether they are efficient, they respect equal sharing (i.e., $\pi_i =$

π_j for all $i, j \in GC$), and they satisfy a weak coalitional rationality argument. As we have already previously stated, formation of the grand coalition does not always coincide with efficiency. Surprisingly, in fact, players could form the grand coalition while "wasting" some value. As also previously observed, investigating about equal sharing, in particular when the grand coalition is formed, is a crucial matter. Previous studies have shown the tendency of individuals to go for the equal sharing (Murnighan and Roth, 1977). It may be speculated that the possibility of communicating through a chat may bring even more often to the equal sharing. Note that the equal division solution is an allocation satisfies both the efficiency and the equal sharing. Finally, we check whether the allocation x satisfies the weak coalitional rationality (WCR), namely, whether $x(S) \geq v(S)\ \forall S \subset N$. In words, the sum of payoffs obtained by members of all the possible coalitions under the realized allocation is no less than their worth, except for the grand coalition. The allocations that are efficient and satisfy WCR (types 1 and 2 in Table 9) belongs to the core. In this sense, checking for efficiency and WCR separately can be interpreted as a way to decompose why some given allocations do not belong to the core. Investigating for WCR, moreover, is essential for checking if, regardless of the possible inefficiency of a proposed share, the allocation is still stable against possible departure of smaller groups of players.

Tables 10 and 11 show the frequencies of observed allocation types, among those formed the grand coalition, in each treatment for games 1 and 4 and games 2 and 3, respectively. See Appendix B for list of the realized allocations, among those formed the grand coalition, in each game and treatment.

For games 1 and 4 shown in Table 10, we observe most allocations belong to the core (i.e., types 1 and 2). Even among those cases that do not belong to the core because they are not efficient (only observed under demand-based), only 1 or 2 fail to satisfy

Table 10: Frequencies of realized allocation types for games 1 and 4

Game 1

	Demand-based			Offer-based		
Allocation Type	No Chat	Chat	Winter	No Chat	Chat	H-MC
1: Eff, Equal, WCR	17	30	0	17	34	11
2: Eff, Not Equal, WCR	15	1	16	17	5	14
3: Eff, Equal, Not WCR	0	0	0	0	0	0
4: Eff, Not Equal, Not WCR	0	0	0	0	0	0
5: Not Eff, Equal, WCR	0	0	0	0	0	0
6: Not Eff, Not Equal, WCR	5	3	5	0	0	0
7: Not Eff, Equal, Not WCR	0	0	0	0	0	0
8: Not Eff, Not Equal, Not WCR	1	0	2	0	0	0
in the core	32	31	16	34	39	25
not in the core	6	3	7	0	0	0
total	38	34	23	34	39	25

Game 4

	Demand-based			Offer-based		
Allocation Type	No Chat	Chat	Winter	No Chat	Chat	H-MC
1: Eff, Equal, WCR	16	24	0	13	26	14
2: Eff, Not Equal, WCR	9	7	16	22	8	16
3: Eff, Equal, Not WCR	0	0	0	0	0	0
4: Eff, Not Equal, Not WCR	0	0	0	0	0	0
5: Not Eff, Equal, WCR	0	2	0	0	0	0
6: Not Eff, Not Equal, WCR	4	1	4	0	0	0
7: Not Eff, Equal, Not WCR	0	0	0	0	0	0
8: Not Eff, Not Equal, Not WCR	0	1	1	0	0	0
in the core	25	31	16	35	34	30
not in the core	4	4	5	0	0	0
total	29	35	21	35	34	30

WCR. Furthermore, the equal division solution (that is, type 1 allocation in these games) accounts for almost a half of the cases in both the demand-based and the offer-based semi-structured procedures without chat. Similar observation can be made for H-MC.

The equal division solution is even more frequently observed in semi-structured procedures when chat is allowed. It is only under Winter that it is not observed. This prevalence of the equal division solution can easily explain the reason behind the aver-

Table 11: Frequencies of realized allocation types for games 2 and 3

Game 2

	Demand-based			Offer-based		
Allocation Type	No Chat	Chat	Winter	No Chat	Chat	H-MC
1: Eff, Equal, WCR	0	0	0	0	0	0
2: Eff, Not Equal, WCR	21	18	25	27	20	7
3: Eff, Equal, Not WCR	0	2	0	0	2	2
4: Eff, Not Equal, Not WCR	2	2	0	3	7	16
5: Not Eff, Equal, WCR	0	0	0	0	0	0
6: Not Eff, Not Equal, WCR	0	0	0	0	0	0
7: Not Eff, Equal, Not WCR	6	3	0	0	0	0
8: Not Eff, Not Equal, Not WCR	7	8	2	0	0	0
in the core	21	18	25	27	20	7
not in the core	15	15	2	3	9	18
total	36	33	27	30	29	25

Game 3

	Demand-based			Offer-based		
Allocation Type	No Chat	Chat	Winter	No Chat	Chat	H-MC
1: Eff, Equal, WCR	0	0	0	0	0	0
2: Eff, Not Equal, WCR	16	7	4	16	17	6
3: Eff, Equal, Not WCR	1	18	0	5	11	9
4: Eff, Not Equal, Not WCR	2	0	0	2	3	4
5: Not Eff, Equal, WCR	0	0	0	0	0	0
6: Not Eff, Not Equal, WCR	2	1	2	0	0	0
7: Not Eff, Equal, Not WCR	0	0	0	0	0	0
8: Not Eff, Not Equal, Not WCR	0	0	0	0	0	0
in the core	16	7	4	16	17	6
not in the core	5	19	2	7	14	13
total	21	26	6	23	31	19

age payoff of player 4s being smaller than the Shapley value, as well as why the Shapley distance due to the violation of additivity tends to be larger with chat than without chat.

For games 2 and 3 shown in Table 11 allocations do not belong to the core (i.e., types 3 to 8) is more frequently observed, compared to games 1 and 4. As in games 1 and 4, failure of the efficiency is observed only in demand-based. Among the efficient allocations, however, there are cases, especially so in offer-based, in which WCR is not satisfied.

This difference, between games 1 and 4 and games 2 and 3 is mainly due to the equal division solution not belonging to the core in the latter. To see this, one can easily check that the worth of a three player coalition $\{2, 3, 4\}$ is greater than the sum of the payoff for these three players under the equal division solution ($75 < 100$ in case of game 2, and $150 < 160$ in case of game 3). However, in game 3, under semi-structured procedure with chat, the equal division solution (type 3) is realized frequently both for the demand-based (18 out of 26) and the offer-based procedure (11 out of 31). Thus, just as in games 1 and 4, the possibility of chat pushes the allocation toward the equal division solution.[19]

However, the chat does not pushes the allocation toward equal division solution when a null player exsts (game 2). For this game, the most frequently observed allocations are type 2, i.e., the efficient, non-equal one that satify WCR (thus belong to the core), except in H-MC. In these allocations, coalition without the null player $\{2, 3, 4\}$ is formed and the worth of grand coalition is fully shared among the members, with one of the members obtaining slightly higher payoff than the others (thus, close to equal sharing, see Appendix B). In the semi-structured demand based procedure without chat, there are also cases where these three players obtain 33 points each leaving 1 point aside (type 6 allocation, not efficient but equal, and does satify WCR).

[19]Interestingly, we observe the following differences in the proposals or demand with and without chat in semi-structured procedures in game 3. In the offer-based case, coalition $\{2, 3, 4\}$ is proposed 29 times out of a total of 154 proposals with chat (18.8%), and without chat, it is 59 times out of total of 226 (26.1%). This difference, however, is not statistically significant (p=0.1269, the proportion test). In the demand-based case, the grand coalition is feasible when four players have submitted demand in 45 out of 98 cases with chat (45.9%) while it is 40 out of 130 cases without chat (30.8%). This difference is significant (p=0.0276, the proportion test). Also, in the demand-based case, when players 2, 3, and 4 have submitted their demand, the sum of their demand is between 151 and 160 (thus, better than equal sharing among four and feasible) 32 out of 157 cases with chat (20.4%) while it is 73 out of 195 cases without chat (37.4%). This difference is also significant ($p<0.001$, the proportion test).

Table 12: Frequencies of allocations when the coalition $\{2,3,4\}$ is formed in game 3

	Demand-Based			Offer-Based		
	No Chat	Chat	Winter	No Chat	Chat	H–MC
Better than the equal division	7	6	8	13	9	4
Others	3	2	19	1	0	1
total	10	8	27	14	9	5

4.4.1 Further investigation of Game 3

Table 6 showed that the coalition $\{2,3,4\}$ was formed frequently in game 3 when players failed to form the grand coalition. As noted above, in this game, the worth of coalition $v(\{2,3,4\}) = 160$ is higher than the sum of payoffs to its three members under the equal division solution. Participants are aware of this as such a discussion appear, although only a few times (4 times both in the offer-based and in the demand-based) in our chat data. As a result, we have observed that without chat, the equal division solution is not frequently observed in this game. Indeed, except for Winter, in most of the cases when coalition $\{2,3,4\}$ was formed, at least one of its members receiving more than 50 (indicated as "Better than the equal division") was observed as shown in Table 12.

5 Concluding remarks

Unstructured, or, in our case, semi-structured bargaining experiments, have been argued to more closely resemble real-world bargaining situations, suggesting that, after many decades, it is time for a revival of unstructured bargaining experiments (Karagözoğlu, 2019). This paper seeks to contribute to this body of literature by experimentally comparing the outcomes of "structured" versus "semi–structured" bargaining experiments.

Specifically, it contrasts the experimental results of two mechanisms that implement the Shapley value (Shapley, 1953) as an ex-ante equilibrium outcome, as considered in Chessa et al. (2023b): simplified versions of the demand-based mechanism proposed by Winter (1994) and the offer-based mechanism proposed by Hart and Mas-Colell (1996), with the outcomes of two corresponding, but much less structured, bargaining procedures. In doing so, this paper also contributes to the literature on the Nash program (Nash, 1953).

We found that semi-structured bargaining procedures led to a significantly higher frequency of grand coalition formation and greater efficiency compared to structured procedures. This outcome is partly because participants in the former could explore a wider range of proposals or demands during negotiations than in the latter.

We also found significant differences in terms of the duration of the negotiations or the likelihood of complete failure of the negotiation (such that no coalition is being formed) between the offer-based and the demand based semi-structured procedures. However, unlike the sharp differences between the outcomes of the demand-based and the offer-based structured bargaining reported by Chessa et al. (2023b) in terms of frequency of the grand coalition formation, efficiency, and the way realized allocations deviate from the Shapley value, no significant differences between the demand-based and the offer-based semi-structured bargaining procedures arose in these dimensions, except that the null player property and additivity are violated by a larger extent under the latter than the former when there is no chat. In terms of the design of bargaining experiments, this result is encouraging because it suggests that when the participants are less constrained in terms of the timing and the number of times they can act, the outcomes of the negotiations become similar regardless of whether the protocol is an offer-based or a demand-based. Finally, the possibility of freefrom communication via online chat in semi-structured bargaining procedures led players toward an equal division outcome.

Our findings suggest that one should carefully consider the potential effects of various restrictions imposed by different mechanisms–such as who can act and when–while also accounting for behavioral biases and cognitive limitations. When it comes to bargaining and coalition formation, in fact, not having various restrictions imposed by different mechanisms may lead to more desirable outcomes. More broadly, our results align with the extensive literature supporting Adam Smith's 'invisible hand' (Rothschild, 1994) and the possibility of cooperation without coercion (Friedman, 2016).

The directions for future research are many and challenging. At first, in our experiment we used only the four games considered by Chessa et al. (2022, 2023a,b), in order to make a direct comparison with previous experimental investigations. As a first step, future studies should consider more varieties of games (with empty-core, non-superadditive, non-convex, with more than four players, or more general games such as partition function games (Thrall and Lucas, 1963)) to better understand the possible impacts of various behavioral biases, such as fairness consideration and loss aversion, in advancing Nash program while incorporating the fruits of the advances in the behavioral and experimental economics. Testing our unstructured and semi-structured bargaining mechanisms for a wider range of games can confirm or question the results of this paper. But the most challenging future direction is to further investigate the impact of our results, and why they differ from some established literature, illustrated in the Introduction of this paper, on the importance of designing and regulating markets and the validation of these theoretical interventions in many experimental and field applications. Future research should investigate the reasons for such differences if our results are applicable to a wide range of bargaining situations. This will allow us to understand which mechanisms are better for facilitating cooperation, if any, and under what circumstances.

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A Instructions

English translation of instructions (of the game and of the experimental software) as well as comprehension quiz are available at `https://osf.io/kqw6n/?view_only=ea41e1284a1347d09760fba82fda37ea`

File names starting with demand-based are for the demand-based treatments, and those starting with offer-based are for the offer-based treatments.

B Allocations within Grand Coalition

In this appendix, we list the frequencies of the realized allocation within the grand coalition (including $\{2, 3, 4\}$ in game 2). In each table, type corresponds to the type of allocation described in Section 4.4, allocation in the form of $\{\pi_1, \pi_2, \pi_3, \pi_4\}$, freq. is the frequency of the realization, efficiency is $\sum \pi_{i\in GC}/v(N)$, Dis. Eq. is the sum of the squared deviation from the equal devision within the grand coalition (GC) $\sum_{i\in GC}(\pi_i - \sum \pi_{i\in GC}/|GC|)^2$, $\in$ Core $= 1$ when the allocation belongs to the core, and $= 0$ otherwise, No. Block is the number of coalitions that can potentially block the realized coalition by offering at least one of its members are better payoff, and Block is the largest coalition among such blocking coalitions. Allocations are sorted according to the type, frequency, efficiency and the distance from the equal devision.

Table 13: Realized allocations. Game 1. Demand-based. No Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
1	25,25,25,25	17	1.000	0.000	1	0	
3	20,25,25,30	2	1.000	50.000	1	0	
3	25,25,20,30	2	1.000	50.000	1	0	
3	25,20,30,25	2	1.000	50.000	1	0	
3	25,25,30,20	1	1.000	50.000	1	0	
3	20,25,30,25	1	1.000	50.000	1	0	
3	20,20,30,30	1	1.000	100.000	1	0	
3	15,25,30,30	1	1.000	150.000	1	0	
3	30,30,15,25	1	1.000	150.000	1	0	
3	20,25,20,35	1	1.000	150.000	1	0	
3	20,15,30,35	1	1.000	250.000	1	0	
3	20,20,20,40	1	1.000	300.000	1	0	
3	10,30,20,40	1	1.000	500.000	1	0	
7	25,25,20,25	1	0.950	18.750	1	0	
7	20,25,25,25	1	0.950	18.750	1	0	
7	20,20,25,25	1	0.900	25.000	1	0	
7	20,25,25,27	1	0.970	26.750	1	0	
7	15,15,20,30	1	0.800	150.000	1	0	
8	15,15,25,5	1	0.600	200.000	0	6	124

Table 14: Realized allocations. Game 1. Demand-based. With Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
1	25,25,25,25	30	1.000	0.000	1	0	
3	25,15,25,35	1	1.000	200.000	1	0	
7	25,23,25,25	1	0.980	3.000	1	0	
7	25,20,25,25	1	0.950	18.750	1	0	
7	15,20,30,25	1	0.900	125.000	1	0	

Table 15: Realized allocations. Game 1. Demand-based. Winter

type	allocation	freq.	efficiency	Dis. Eq.	∈ Core	No. Block	Block
3	20,20,30,30	2	1.000	100.000	1	0	
3	29,26,20,25	1	1.000	42.000	1	0	
3	25,25,20,30	1	1.000	50.000	1	0	
3	25,30,20,25	1	1.000	50.000	1	0	
3	30,25,25,20	1	1.000	50.000	1	0	
3	20,25,30,25	1	1.000	50.000	1	0	
3	20,30,30,20	1	1.000	100.000	1	0	
3	34,23,23,20	1	1.000	114.000	1	0	
3	30,25,15,30	1	1.000	150.000	1	0	
3	30,30,15,25	1	1.000	150.000	1	0	
3	14,25,31,30	1	1.000	182.000	1	0	
3	30,30,10,30	1	1.000	300.000	1	0	
3	15,20,25,40	1	1.000	350.000	1	0	
3	5,30,30,35	1	1.000	550.000	1	0	
3	14,23,15,48	1	1.000	754.000	1	0	
7	25,25,20,15	1	0.850	68.750	1	0	
7	32,15,17,28	1	0.920	206.000	1	0	
7	38,21,15,25	1	0.990	284.750	1	0	
7	10,34,25,25	1	0.940	297.000	1	0	
7	35,10,30,20	1	0.950	368.750	1	0	
8	25,20,10,25	1	0.800	150.000	0	1	234
8	5,33,30,12	1	0.800	558.000	0	3	134

Table 16: Realized allocations. Game 1. Offer-based. No Chat.

type	allocation	freq.	efficiency	Dis. Eq.	∈ Core	No. Block	Block
1	25,25,25,25	17	1.000	0.000	1	0	
3	20,25,25,30	3	1.000	50.000	1	0	
3	10,30,30,30	3	1.000	300.000	1	0	
3	22,26,26,26	2	1.000	12.000	1	0	
3	25,25,24,26	1	1.000	2.000	1	0	
3	24,26,26,24	1	1.000	4.000	1	0	
3	23,25,25,27	1	1.000	8.000	1	0	
3	21,26,26,27	1	1.000	22.000	1	0	
3	20,25,27,28	1	1.000	38.000	1	0	
3	19,27,27,27	1	1.000	48.000	1	0	
3	20,22,28,30	1	1.000	68.000	1	0	
3	20,21,30,29	1	1.000	82.000	1	0	
3	16,28,28,28	1	1.000	108.000	1	0	

Table 17: Realized allocations. Game 1. Offer-based. With Chat.

type	allocation	freq.	efficiency	Dis. Eq.	∈ Core	No. Block	Block
1	25,25,25,25	34	1.000	0.000	1	0	
3	10,30,30,30	2	1.000	300.000	1	0	
3	20,25,25,30	1	1.000	50.000	1	0	
3	16,27,27,30	1	1.000	114.000	1	0	
3	8,30,30,32	1	1.000	388.000	1	0	

Table 18: Realized allocations. Game 1. Offer-based. H-MC.

type	allocation	freq.	efficiency	Dis. Eq.	∈ Core	No. Block	Block
1	25,25,25,25	11	1.000	0.000	1	0	
3	23,31,23,23	3	1.000	48.000	1	0	
3	20,25,25,30	2	1.000	50.000	1	0	
3	28,24,24,24	1	1.000	12.000	1	0	
3	21,25,25,29	1	1.000	32.000	1	0	
3	23,23,31,23	1	1.000	48.000	1	0	
3	22,22,31,25	1	1.000	54.000	1	0	
3	21,23,31,25	1	1.000	56.000	1	0	
3	34,22,22,22	1	1.000	108.000	1	0	
3	23,35,22,20	1	1.000	138.000	1	0	
3	15,25,25,35	1	1.000	200.000	1	0	
3	15,20,20,45	1	1.000	550.000	1	0	

Table 19: Realized allocations. Game 2. Demand-based. No Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
3	0,30,30,40	5	1.000	66.667	1	0	
3	0,33,32,35	3	1.000	4.667	1	0	
3	0,30,35,35	3	1.000	16.667	1	0	
3	0,35,32,33	2	1.000	4.667	1	0	
3	0,29,31,40	2	1.000	68.667	1	0	
3	0,25,25,50	2	1.000	416.667	1	0	
3	0,33,33,34	1	1.000	0.667	1	0	
3	0,33,30,37	1	1.000	24.667	1	0	
3	0,33,27,40	1	1.000	84.667	1	0	
3	0,28,27,45	1	1.000	204.667	1	0	
4	10,20,30,40	1	1.000	500.000	0	1	234
4	3,28,31,38	1	1.000	698.000	0	1	234
6	0,33,33,33	4	0.990	0.000	0	1	234
6	0,30,30,30	2	0.900	0.000	0	1	234
8	0,30,25,35	1	0.900	50.000	0	1	234
8	0,25,27,35	1	0.870	56.000	0	1	234
8	0,35,25,35	1	0.950	66.667	0	1	234
8	0,20,30,35	1	0.850	116.667	0	1	234
8	0,30,22,40	1	0.920	162.667	0	1	234
8	0,22,25,50	1	0.970	472.667	0	1	234
8	1,33,33,30	1	0.970	726.750	0	1	234

Table 20: Realized allocations. Game 2. Demand-based. With Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
2	25,25,25,25	2	1.000	0.000	0	3	234
3	0,35,30,35	5	1.000	16.667	1	0	
3	0,33,34,33	2	1.000	0.667	1	0	
3	0,33,33,34	2	1.000	0.667	1	0	
3	0,34,33,33	1	1.000	0.667	1	0	
3	0,32,33,35	1	1.000	4.667	1	0	
3	0,30,35,35	1	1.000	16.667	1	0	
3	0,30,30,40	1	1.000	66.667	1	0	
3	0,30,40,30	1	1.000	66.667	1	0	
3	0,25,40,35	1	1.000	116.667	1	0	
3	0,35,25,40	1	1.000	116.667	1	0	
3	0,25,35,40	1	1.000	116.667	1	0	
3	0,20,30,50	1	1.000	466.667	1	0	
4	25,20,25,30	1	1.000	50.000	0	2	234
4	1,33,33,33	1	1.000	768.000	0	1	234
6	0,33,33,33	2	0.990	0.000	0	1	234
6	0,30,30,30	1	0.900	0.000	0	1	234
8	0,30,33,30	1	0.930	6.000	0	1	234
8	0,30,35,33	1	0.980	12.667	0	1	234
8	0,33,30,35	1	0.980	12.667	0	1	234
8	0,30,32,35	1	0.970	12.667	0	1	234
8	0,30,30,35	1	0.950	16.667	0	1	234
8	0,35,25,35	1	0.950	66.667	0	1	234
8	0,22,30,35	1	0.870	86.000	0	1	234
8	7,25,27,40	1	0.990	552.750	0	1	234

Table 21: Realized allocations. Game 2. Demand-based. Winter

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
3	0,30,30,40	3	1.000	66.667	1	0	
3	0,25,40,35	3	1.000	116.667	1	0	
3	0,35,25,40	3	1.000	116.667	1	0	
3	0,30,35,35	2	1.000	16.667	1	0	
3	0,25,35,40	2	1.000	116.667	1	0	
3	0,25,30,45	2	1.000	216.667	1	0	
3	0,34,34,32	1	1.000	2.667	1	0	
3	0,32,33,35	1	1.000	4.667	1	0	
3	0,30,37,33	1	1.000	24.667	1	0	
3	0,30,39,31	1	1.000	48.667	1	0	
3	0,32,29,39	1	1.000	52.667	1	0	
3	0,30,29,41	1	1.000	88.667	1	0	
3	0,25,41,34	1	1.000	128.667	1	0	
3	0,30,25,45	1	1.000	216.667	1	0	
3	0,29,25,46	1	1.000	248.667	1	0	
3	0,35,20,45	1	1.000	316.667	1	0	
8	0,25,30,40	1	0.950	116.667	0	1	234
8	0,25,25,42	1	0.920	192.667	0	1	234

Table 22: Realized allocations. Game 2. Offer-based. No Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
3	0,30,30,40	10	1.000	66.667	1	0	
3	0,33,33,34	4	1.000	0.667	1	0	
3	0,30,35,35	3	1.000	16.667	1	0	
3	0,34,33,33	2	1.000	0.667	1	0	
3	0,31,31,38	2	1.000	32.667	1	0	
3	0,33,34,33	1	1.000	0.667	1	0	
3	0,32,34,34	1	1.000	2.667	1	0	
3	0,31,34,35	1	1.000	8.667	1	0	
3	0,34,31,35	1	1.000	8.667	1	0	
3	0,32,32,36	1	1.000	10.667	1	0	
3	0,29,29,42	1	1.000	112.667	1	0	
4	20,30,25,25	1	1.000	50.000	0	2	234
4	10,30,30,30	1	1.000	300.000	0	1	234
4	1,33,33,33	1	1.000	768.000	0	1	234

Table 23: Realized allocations. Game 2. Offer-based. With Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
2	25,25,25,25	2	1.000	0.000	0	3	234
3	0,30,30,40	7	1.000	66.667	1	0	
3	0,33,33,34	6	1.000	0.667	1	0	
3	0,32,32,36	2	1.000	10.667	1	0	
3	0,34,33,33	1	1.000	0.667	1	0	
3	0,32,33,35	1	1.000	4.667	1	0	
3	0,33,32,35	1	1.000	4.667	1	0	
3	0,35,30,35	1	1.000	16.667	1	0	
3	0,30,35,35	1	1.000	16.667	1	0	
4	15,25,25,35	2	1.000	200.000	0	1	234
4	20,25,25,30	1	1.000	50.000	0	1	234
4	10,30,30,30	1	1.000	300.000	0	1	234
4	10,28,28,34	1	1.000	324.000	0	1	234
4	7,28,28,37	1	1.000	486.000	0	1	234
4	1,33,33,33	1	1.000	768.000	0	1	234

Table 24: Realized allocations. Game 2. Offer-based. H–MC.

type	allocation	freq.	efficiency	Dis. Eq.	∈ Core	No. Block	Block
2	25,25,25,25	2	1.000	0.000	0	3	234
3	0,33,33,34	2	1.000	0.667	1	0	
3	0,33,34,33	1	1.000	0.667	1	0	
3	0,30,35,35	1	1.000	16.667	1	0	
3	0,37,27,36	1	1.000	60.667	1	0	
3	0,30,30,40	1	1.000	66.667	1	0	
3	0,25,40,35	1	1.000	116.667	1	0	
4	15,25,25,35	3	1.000	200.000	0	1	234
4	24,24,28,24	1	1.000	12.000	0	3	234
4	25,20,25,30	1	1.000	50.000	0	2	234
4	21,23,24,32	1	1.000	70.000	0	1	234
4	21,21,27,31	1	1.000	72.000	0	2	234
4	21,23,23,33	1	1.000	88.000	0	1	234
4	22,22,22,34	1	1.000	108.000	0	2	234
4	15,25,30,30	1	1.000	150.000	0	1	234
4	20,22,22,36	1	1.000	164.000	0	2	234
4	20,20,20,40	1	1.000	300.000	0	2	234
4	11,27,27,35	1	1.000	304.000	0	1	234
4	10,25,30,35	1	1.000	350.000	0	1	234
4	10,27,27,36	1	1.000	354.000	0	1	234
4	10,20,40,30	1	1.000	500.000	0	2	234

Table 25: Realized allocations. Game 3. Demand-based. No Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
2	50,50,50,50	1	1.000	0.000	0	1	234
3	40,50,50,60	3	1.000	200.000	1	0	
3	40,53,50,57	2	1.000	158.000	1	0	
3	40,60,50,50	2	1.000	200.000	1	0	
3	40,56,50,54	1	1.000	152.000	1	0	
3	40,55,40,65	1	1.000	450.000	1	0	
3	35,50,50,65	1	1.000	450.000	1	0	
3	35,45,53,67	1	1.000	548.000	1	0	
3	30,50,60,60	1	1.000	600.000	1	0	
3	40,50,40,70	1	1.000	600.000	1	0	
3	30,60,60,50	1	1.000	600.000	1	0	
3	25,60,45,70	1	1.000	1150.000	1	0	
3	20,50,70,60	1	1.000	1400.000	1	0	
4	50,50,40,60	1	1.000	200.000	0	1	234
4	47,40,53,60	1	1.000	218.000	0	1	234
7	30,50,50,60	1	0.950	475.000	1	0	
7	15,50,60,70	1	0.975	1718.750	1	0	

Table 26: Realized allocations. Game 3. Demand-based. With Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
2	50,50,50,50	18	1.000	0.000	0	1	234
3	40,50,60,50	2	1.000	200.000	1	0	
3	30,60,50,60	1	1.000	600.000	1	0	
3	25,60,55,60	1	1.000	850.000	1	0	
3	25,50,60,65	1	1.000	950.000	1	0	
3	20,50,60,70	1	1.000	1400.000	1	0	
3	10,50,70,70	1	1.000	2400.000	1	0	
7	15,50,50,60	1	0.875	1168.750	1	0	

Table 27: Realized allocations. Game 3. Demand-based. Winter.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
3	30,51,45,74	1	1.000	1002.000	1	0	
3	20,50,65,65	1	1.000	1350.000	1	0	
3	10,70,60,60	1	1.000	2200.000	1	0	
3	11,70,50,69	1	1.000	2282.000	1	0	
7	20,45,84,50	1	0.995	2080.750	1	0	
7	35,30,40,90	1	0.975	2318.750	1	0	

Table 28: Realized allocations. Game 3. Offer-based. No Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
2	50,50,50,50	5	1.000	0.000	0	1	234
3	35,51,51,63	2	1.000	396.000	1	0	
3	25,55,55,65	2	1.000	900.000	1	0	
3	20,60,60,60	2	1.000	1200.000	1	0	
3	10,60,60,70	2	1.000	2200.000	1	0	
3	40,55,55,50	1	1.000	150.000	1	0	
3	38,55,49,58	1	1.000	234.000	1	0	
3	35,55,55,55	1	1.000	300.000	1	0	
3	31,54,54,61	1	1.000	514.000	1	0	
3	30,55,55,60	1	1.000	550.000	1	0	
3	30,50,50,70	1	1.000	800.000	1	0	
3	25,55,60,60	1	1.000	850.000	1	0	
3	25,60,55,60	1	1.000	850.000	1	0	
4	47,47,47,59	1	1.000	108.000	0	1	234
4	45,45,45,65	1	1.000	300.000	0	1	234

Table 29: Realized allocations. Game 3. Offer-based. With Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
2	50,50,50,50	11	1.000	0.000	0	1	234
3	30,55,55,60	4	1.000	550.000	1	0	
3	40,50,50,60	3	1.000	200.000	1	0	
3	35,55,55,55	2	1.000	300.000	1	0	
3	35,50,50,65	2	1.000	450.000	1	0	
3	20,50,50,80	2	1.000	1800.000	1	0	
3	38,52,52,58	1	1.000	216.000	1	0	
3	35,52,53,60	1	1.000	338.000	1	0	
3	31,53,53,63	1	1.000	548.000	1	0	
3	25,55,55,65	1	1.000	900.000	1	0	
4	45,51,51,53	1	1.000	36.000	0	1	234
4	45,50,50,55	1	1.000	50.000	0	1	234
4	41,53,53,53	1	1.000	108.000	0	1	234

Table 30: Realized allocations. Game 3. Offer-based. H–MC.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
2	50,50,50,50	9	1.000	0.000	0	1	234
3	30,50,50,70	3	1.000	800.000	1	0	
3	40,50,50,60	2	1.000	200.000	1	0	
3	40,40,80,40	1	1.000	1200.000	1	0	
4	50,55,40,55	1	1.000	150.000	0	1	234
4	50,45,45,60	1	1.000	150.000	0	1	234
4	50,50,40,60	1	1.000	200.000	0	1	234
4	55,35,55,55	1	1.000	300.000	0	1	234

Table 31: Realized allocations. Game 4. Demand-based. No Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
1	50,50,50,50	16	1.000	0.000	1	0	
3	40,50,50,60	2	1.000	200.000	1	0	
3	56,50,50,44	1	1.000	72.000	1	0	
3	50,40,50,60	1	1.000	200.000	1	0	
3	44,43,50,63	1	1.000	254.000	1	0	
3	40,60,40,60	1	1.000	400.000	1	0	
3	50,30,60,60	1	1.000	600.000	1	0	
3	35,40,50,75	1	1.000	950.000	1	0	
3	40,40,40,80	1	1.000	1200.000	1	0	
7	50,50,50,45	1	0.975	18.750	1	0	
7	45,40,40,55	1	0.900	150.000	1	0	
7	30,30,50,70	1	0.900	1100.000	1	0	
7	30,50,45,50	1	0.875	268.750	1	0	

Table 32: Realized allocations. Game 4. Demand-based. With Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
1	50,50,50,50	24	1.000	0.000	1	0	
3	40,50,50,60	3	1.000	200.000	1	0	
3	45,52,53,50	1	1.000	38.000	1	0	
3	50,50,40,60	1	1.000	200.000	1	0	
3	30,50,60,60	1	1.000	600.000	1	0	
3	30,40,50,80	1	1.000	1400.000	1	0	
5	40,40,40,40	2	0.800	0.000	1	0	
7	35,50,50,50	1	0.925	168.750	1	0	
8	35,40,50,40	1	0.825	118.750	0	1	124

Table 33: Realized allocations. Game 4. Demand-based. Winter.

type	allocation	freq.	efficiency	Dis. Eq.	∈ Core	No. Block	Block
3	55,45,45,55	1	1.000	100.000	1	0	
3	60,40,50,50	1	1.000	200.000	1	0	
3	40,50,60,50	1	1.000	200.000	1	0	
3	50,40,62,48	1	1.000	248.000	1	0	
3	35,50,65,50	1	1.000	450.000	1	0	
3	40,40,70,50	1	1.000	600.000	1	0	
3	30,50,60,60	1	1.000	600.000	1	0	
3	50,63,30,57	1	1.000	618.000	1	0	
3	25,60,60,55	1	1.000	850.000	1	0	
3	30,40,70,60	1	1.000	1000.000	1	0	
3	66,30,35,69	1	1.000	1242.000	1	0	
3	30,79,61,30	1	1.000	1762.000	1	0	
3	50,50,20,80	1	1.000	1800.000	1	0	
3	40,80,20,60	1	1.000	2000.000	1	0	
3	40,30,40,90	1	1.000	2200.000	1	0	
3	53,13,54,80	1	1.000	2294.000	1	0	
7	70,45,50,25	1	0.950	1025.000	1	0	
7	40,40,30,80	1	0.950	1475.000	1	0	
7	60,66,25,35	1	0.930	1157.000	1	0	
7	50,50,10,60	1	0.850	1475.000	1	0	
8	15,50,40,50	1	0.775	818.750	0	2	134

Table 34: Realized allocations. Game 4. Offer-based. No Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
1	50,50,50,50	13	1.000	0.000	1	0	
3	40,50,50,60	6	1.000	200.000	1	0	
3	47,51,51,51	2	1.000	12.000	1	0	
3	35,55,55,55	2	1.000	300.000	1	0	
3	49,51,50,50	1	1.000	2.000	1	0	
3	48,50,51,51	1	1.000	6.000	1	0	
3	51,51,51,47	1	1.000	12.000	1	0	
3	52,45,51,52	1	1.000	34.000	1	0	
3	44,52,52,52	1	1.000	48.000	1	0	
3	50,45,55,50	1	1.000	50.000	1	0	
3	50,50,45,55	1	1.000	50.000	1	0	
3	43,51,51,55	1	1.000	76.000	1	0	
3	42,52,52,54	1	1.000	88.000	1	0	
3	40,50,55,55	1	1.000	150.000	1	0	
3	35,50,50,65	1	1.000	450.000	1	0	
3	20,65,50,65	1	1.000	1350.000	1	0	

Table 35: Realized allocations. Game 4. Offer-based. With Chat.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
1	50,50,50,50	26	1.000	0.000	1	0	
3	40,50,50,60	4	1.000	200.000	1	0	
3	45,50,50,55	2	1.000	50.000	1	0	
3	45,55,50,50	1	1.000	50.000	1	0	
3	30,55,55,60	1	1.000	550.000	1	0	

Table 36: Realized allocations. Game 4. Offer-based. H–MC.

type	allocation	freq.	efficiency	Dis. Eq.	$\in$ Core	No. Block	Block
1	50,50,50,50	14	1.000	0.000	1	0	
3	40,50,50,60	3	1.000	200.000	1	0	
3	45,65,45,45	2	1.000	300.000	1	0	
3	55,50,50,45	1	1.000	50.000	1	0	
3	47,59,47,47	1	1.000	108.000	1	0	
3	55,55,40,50	1	1.000	150.000	1	0	
3	35,55,55,55	1	1.000	300.000	1	0	
3	40,44,68,48	1	1.000	464.000	1	0	
3	50,40,40,70	1	1.000	600.000	1	0	
3	41,73,41,45	1	1.000	716.000	1	0	
3	40,75,40,45	1	1.000	850.000	1	0	
3	80,40,40,40	1	1.000	1200.000	1	0	
3	30,35,60,75	1	1.000	1350.000	1	0	
3	30,40,80,50	1	1.000	1400.000	1	0	