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An experimental Nash program: A comparison of structured versus semi-structured bargaining experiments

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Abstract

While market design advocates for 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 grand coalition formation and higher efficiency in the semi-structured than in the structured procedures regardless of whether they are 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, the possibility of free-form chat induces an equal division more frequently than occurs without it. Our results suggest that when it comes to bargaining and coalition formation, not having various restrictions imposed by different mechanisms may lead to more desirable outcomes.

Keywords: Bargaining procedures; Nash program; Shapley value

JEL code: C70; C71; C92

1. Introduction

For decades, economists, particularly game theorists, have played a crucial role in assisting legislators, regulators, lawyers, and judges in designing markets. They have been instrumental in developing complex markets in the classical theory of auctions (Vickrey, 1961; Milgrom & Weber, 1982a, 1982b), in labor clearing houses for American doctors obtaining their first jobs (Roth & Peranson, 1999), and markets for electric power (Wilson, 2002; Cramton, 2017) to name but a few. Additionally, they have proposed allocation procedures for markets that do not use prices, such as coalition formation (Kahan & Rapoport, 2014), school choice (Roth, 1985), live-donor kidney transplantation (Roth et al., 2004, 2007), and 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.

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Bargaining is one of the most ubiquitous and effective forms of market interaction between potentially conflicting or cooperating agents and is 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 (e.g., 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 & Levin, 1986; Kagel & Roth, 2000). Then, the goals achieved through extensive theoretical research on mechanism design – including bargaining procedures design – have been well supported and documented by a substantial body of experimental literature (Smith, 1967; Cox et al., 1988; Denton et al., 2001; Brosig et al., 2003; Chen & Sönmez, 2006) and numerous field applications (Dickerson et al., 2012). However, there is a field in which experiments have shown a certain fragility in validating the proposed theoretical mechanisms and their appealing results: coalition formation theory (Okada & Riedl, 2005; Abe et al., 2021).

Coalitions are means-oriented, and frequently temporary, alliances among individuals or groups who may have different initial goals. In many situations, forming a coalition is advantageous to both individuals and groups. Coalition formation behavior is a pervasive aspect of social life (Gamson, 1961) and thus a crucial matter in economics (Konishi & Ray, 2003; Kahan & Rapoport, 2014). Theories of coalition formation have been developed in many models 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 & Kravitz, 1983), and computer science (Dang et al., 2006).

In this paper, we focus on coalition formation from the classical perspective of game theorists, with cooperative game theory serving as the means we use in our investigation. This theory emerged alongside noncooperative game theory after the foundational paper by John von Neumann (1928). Then, the active collaboration of John von Neumann and Oskar Morgenstern culminated in the renowned book *Theory of Games and Economic Behavior* (von Neumann & Morgenstern, 1944). Despite a common origin founded on the well-established assumption of the rationality of individuals, noncooperative game theory and cooperative game theory have advanced for decades on two different paths, with the gap between the two becoming more and more apparent over the years.

However, there has been a significant effort to bridge these two branches of game theory. This strand of literature is known as the Nash (1953) program. This agenda aims to provide noncooperative mechanisms to implement cooperative interactions (Serrano, 2005, 2008, 2014, 2021, for surveys). The theory predicts that at equilibrium, individuals, guided by the proposed strategic mechanisms in their interactions, will manage to cooperate efficiently and share the proceeds according to well-known cooperative solutions, such as the Shapley value. These mechanisms reconcile and integrate the two approaches by enabling players, within a specific allocation context, to engage in constrained bargaining processes and reach a stable outcome without requiring an external intermediary. The rationale behind this design is that if the same outcome can be reached through different paths, the solution is likely to be more robust. While many authors have contributed to the development of the Nash program, 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, 2023b) have conducted a series of experiments comparing different mechanisms that 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,

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the experimental results show that in many cases, individuals fail to cooperate. These results are in line with other experimental investigations of theoretical models for coalition formation (Kahan & Rapoport, 1980a; Rapoport & Kahan, 1984).

A closer look at the structure of these bargaining procedures in the context of the Nash program suggests that this failure may be attributed to two factors. First, many of these mechanisms are expected to provide a fair allocation a priori, but in practice, the proposed divisions depend heavily on the specific implementation of the mechanism in a given scenario. This includes the order in which individuals participate in the mechanism, to the detriment of those who intervene last, with the first mover often being selected simply through a random choice (Chessa et al., 2023a, 2023b). This feature then results in expected final shares that are clearly unfair to those individuals who are not lucky enough to be selected as first movers. Second, individuals explicitly retain the ability to reject a given final allocation even after agreeing to participate in a mechanism. This issue becomes even more evident in cases of unfair allocations, which are then rejected by one or more individuals, thus excluding any possibility of a complete future agreement.

In the present study, we aim to shed light on whether reducing the structural constraints in bargaining procedures can lead to higher levels of cooperation among individuals. More freedom in bargaining would grant individuals greater flexibility to adjust the proposed divisions and achieve a broader consensus. Indeed, previous studies have already highlighted the importance of shifting the focus toward more unstructured bargaining experiments and advocate 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 design of a computer interface necessarily imposes some structure on the bargaining procedure. For example, Shinoda & Funaki (2019) conducted what they call a computerized "unstructured" three-player bargaining experiment. Participants could freely propose a coalition and an associated allocation that was feasible among the members of the proposed coalition. Participants were also free to modify their proposal anytime during the negotiation, and 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-player games that model negotiable conflicts involving two weak players and one strong player, Kahan & Rapoport (1980a) considered two communication conditions: 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 than those considered in Chessa et al. (2022, 2023a, 2023b), 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 members, freely make their demand for them to join a coalition) "semi-structured" bargaining experiment. We call these experiments semi-structured (Duffy et al., 2025) because, as noted above, while they are much less structured compared to the structured bargaining experiments considered by Chessa et al. (2022, 2023a, 2023b), 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 & 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. We also vary (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 mechanisms can result in outcomes satisfying very different properties. Then, we contrast (c) 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 for our analysis.

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We find that semi-structured experiments, both offer-based and demand-based, result in a higher frequency of grand coalition formation and more efficiency than structured ones. Unlike Chessa et al. (2023b), who find significant differences in the outcomes of offer- versus demand-based procedures, we do not find significant differences between the two, regardless of the possibility of free-form communication. The latter result suggests that the exact procedure may have little impact on outcomes.

We further analyze the negotiation dynamics of offers and demands, first using two examples from semi-structured experiments to demonstrate that agents tend to converge toward efficient outcomes, as well as the Shapley value and equal division, during the negotiation process. We then show that this tendency arises primarily from the flexibility to repeatedly adjust offers and demands over time, a feature absent in structured mechanisms.

The rest of the paper is organized as follows. Section 2 illustrates the theoretical background, including the presentation of the structured mechanisms by Winter (1994) and Hart & Mas-Colell (1996) previously experimentally investigated in Chessa et al. (2023b). Section 3 presents the design of our new experiments and the newly defined semi-structured bargaining procedures. The results of our new experiments, with a comparison with our previous experiments, are presented and discussed in Section 4, while Section 5 concludes.

2. Theoretical background

In Section 2.1, we provide some theoretical definitions. Then, in Section 2.2, we present the two structured mechanisms that we analyzed in our previous experimental study (Chessa et al., 2023b) and that we question and compare with similar but semi-structured mechanisms in this paper.

2.1. Cooperative transferable utility games and solutions

Let $N = \{1, \dots, n\}$ 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 $\mathcal{G}^N$. 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 null player is a player who contributes nothing to any coalition.

The most famous solution concept for cooperative TU games, the *Shapley value*, fairly distributes the total contribution of all players in a system by averaging their marginal contributions across all possible participation orders. It is defined as follows:

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

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

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

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

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2.2. Winter and Hart and Mas-Colell mechanisms

Winter (1994) introduced a bargaining procedure based on sequential demands within strictly convex cooperative games.[1] In these games, cooperation becomes increasingly attractive, generating a snowball effect that leads to the formation of the grand coalition. 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 procedure 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 T periods have been completed. In Chessa et al. (2023b), we considered a one-period implementation in which players with unmet demands at the end of the first period receive their individual value.[2]

Winter (1994) demonstrated that this mechanism has a unique subgame perfect equilibrium that 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 & Mas-Colell (1996) introduced a bargaining procedure designed for monotonic cooperative games,[3] which is a less stringent condition than the strict convexity required by Winter mechanism. In the following, we present a simplified version of the mechanism as implemented in Chessa et al. (2023b). In this mechanism, the bargaining procedure 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 & Mas-Colell (1996) allows 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 & 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. This game represents a meaningful example, as it is very similar to the games implemented in our experimental studies. This game satisfies the conditions required by both the Winter and Hart & Mas-Colell (H-MC) mechanisms. The Shapley value for this game is represented by the vector

[1] A game $v \in \mathcal{G}^N$ is *strictly convex* if $v(S) + v(T) < v(S \cup T) + v(S \cap T)$, for each $S, T \subseteq N$.

[2] 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.

[3] A game $v \in \mathcal{G}^N$ is *monotonic* if $v(S) \leq v(T)$ for each $S \subseteq T \subseteq N$.

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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

$\phi(v) = \left(\frac{80}{3}, \frac{110}{3}, \frac{110}{3}\right) \approx (26.67, 36.67, 36.67)$, 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; that is, $v(N) - v(N \setminus \{1\})$. Suppose further that the order of players in the Winter mechanism is 1, 2, and 3. In this case, the a posteriori equilibrium payoff for the Winter mechanism is given by the vector $(40, 40, 20)$, where player 2 demands her marginal contribution $v(\{2, 3\}) - v(\{3\})$, and player 3 claims 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 $(40, 30, 30)$. Repeating the above argument for every order, we obtain the a posteriori equilibrium payoffs summarized in Table 2.

We can observe how the payoff shares are strongly affected by the order in which players are asked to make their demand or offer. In particular, the player who moves first has a significant advantage in the corresponding a posteriori equilibrium, and this represents a clear drawback of these structured mechanisms. To stress this anomaly in an even more extreme case, consider the following three-player glove game (Shapley & Shubik, 1969), where players 1 and 2 each own a left-handed glove, and player 3 owns a right-handed glove. Only a matched pair is worth one unit of value, such that $v(\{1, 3\}) = v(\{2, 3\}) = v(\{1, 2, 3\}) = 1$ and zero otherwise. The a posteriori and the a priori – coinciding with the Shapley value – equilibrium payoffs are summarized in Table 3.

Thus, under the Winter mechanism, for every player order, we observe that the last player is always expected to receive and accept a payoff of zero. This also happens when the last player is player 3, who has a central role in our glove game as she is the only one necessary for the formation of a coalition of nonzero worth.

In this paper, we posit that this could be one reason for the limited success in experimental implementation of structured mechanisms, as observed in Chessa et al. (2023b).

3. The experimental design

We first describe in Section 3.1 the four-player bargaining games we consider in our experiment. We then explain our four treatments in Section 3.2, based on our newly defined semi-structured bargaining procedures, which are presented in Section 3.3 and in Section 3.4. At each step, we systematically provide a comparison with the experimental design of the previous experiments in Chessa et al. (2023b).

3.1. The games

We consider the four four-player games shown in Table 4. These games are the same as those considered in Chessa et al. (2022, 2023a, 2023b). This is to allow a direct comparison of the results in Chessa et al. (2023b). The Shapley values of the four games are presented in Table 5. 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, 2023b), each participant played all four games twice. The order of games was counterbalanced across sessions. That is, participants played these four games in one of the following four orders: 1234, 2143, 3412, and 4321. At the beginning of a new round,

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Table 2. A posteriori equilibrium payoffs

Order	Winter	H-MC
123	$(40, 40, 20)$	$(40, 30, 30)$
132	$(40, 20, 40)$	$(40, 30, 30)$
213	$(30, 50, 20)$	$(20, 50, 30)$
231	$(10, 50, 40)$	$(20, 50, 30)$
312	$(30, 20, 50)$	$(20, 30, 50)$
321	$(10, 40, 50)$	$(20, 30, 50)$
Shapley value $\phi(v)$	$(\frac{80}{3}, \frac{110}{3}, \frac{110}{3})$	$(\frac{80}{3}, \frac{110}{3}, \frac{110}{3})$

Table 3. A posteriori and a priori equilibrium payoffs in the glove game

Order	Winter	H-MC
123	$(0, 1, 0)$	$(0, \frac{1}{2}, \frac{1}{2})$
132	$(0, 0, 1)$	$(0, \frac{1}{2}, \frac{1}{2})$
213	$(1, 0, 0)$	$(\frac{1}{2}, 0, \frac{1}{2})$
231	$(0, 0, 1)$	$(\frac{1}{2}, 0, \frac{1}{2})$
312	$(0, 0, 1)$	$(0, 0, 1)$
321	$(0, 0, 1)$	$(0, 0, 1)$
Shapley value $\phi(v)$	$(\frac{1}{6}, \frac{1}{6}, \frac{4}{6})$	$(\frac{1}{6}, \frac{1}{6}, \frac{4}{6})$

Table 4. 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
$v_3(S)$	$= v_1(S) + v_2(S)$														
$v_4(S)$	$= 2v_1(S)$														

Table 5. 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

participants were randomly rematched into groups of four players, and their roles were randomly reassigned within the newly created groups.[4]

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

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3.2. Treatments

In our 2×2 between-subjects design, we vary (a) whether participants communicate freely via online chat during the negotiation and (b) whether the negotiation is offer-based or demand-based. Then, (c) we contrast the results of these four semi-structured bargaining procedures with the results of the structured offer-based and demand-based experiment in Chessa et al. (2023b). In total, we thus present analyses related to comparisons of the results of six different treatments corresponding to six different bargaining procedures.

In the two semi-structured bargaining procedures with free-form communication, participants could freely send chat messages (except for messages that could identify them and those that could insult others). Messages could be seen by everyone in the same group and could be sent at any time during gameplay.

In all four semi-structured bargaining procedures, the total maximum duration of a negotiation was randomly determined to be between 300 and 360 seconds. Participants were informed that a negotiation could continue for at least 300 seconds, but its end would terminate at a randomly chosen moment during the 60 seconds following the 60-second mark. The negotiation could end earlier if a grand coalition was formed, or when only one player remained who was not in any coalition. By contrast, in the structured bargaining procedures in Chessa et al. (2023b) an overall time limit was not set, but one was established for each step of the negotiation. A time limit of 60 seconds was set for making a demand (Winter) or an offer (H-MC), and 30 seconds were allocated for choosing a coalition (Winter) or deciding whether to approve or reject a proposal (H-MC).

Figure 1 represents the six bargaining procedures implemented in the six different treatments and analyzed in this paper, highlighting their main features and differences. On the left of the tree, we present the two structured mechanisms, Winter and H-MC. On the right are the four semi-structured mechanisms, described in greater detail in Sections 3.3 and 3.4. A key difference between structured and semi-structured mechanisms is highlighted here. In a structured mechanism, the bargaining is started by the individual who has been selected as first mover, randomly and by the algorithm. In semi-structured mechanisms, by contrast, any individual can decide to be the first mover.

We now describe the demand-based and offer-based bargaining procedures of our semi-structured mechanisms in detail. These procedures represent the unstructured version of the Winter and the H-MC mechanisms, respectively, presented in Section 2.2 and the object of the previous study by Chessa et al. (2023b).

3.3. Demand-based bargaining procedure

In this procedure, at any point during a negotiation, players are free to demand points they want to obtain. Note that in doing so, players are not proposing a coalition. Instead, they are expressing the points they want to receive for joining a coalition. Each player can make at most one demand at any time during the negotiation, but players are free to modify their demands at any time 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. We exclude a single-player coalition because it is the default outcome for the player when she 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 she is currently agreeing to form, they need to withdraw from their 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. The negotiation continues with the

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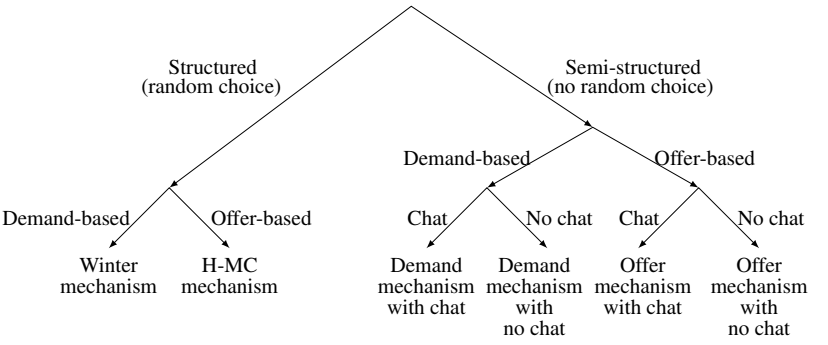


Fig. 1 Representation of the six treatments based on the six different bargaining mechanisms

remaining players. If only one player remains, the negotiation ends. A player without an agreed coalition at the end of the negotiation (either because of the time limit or because she is the only player left) obtains the singleton value.

3.4. Offer-based bargaining procedure

This procedure is similar to the one that Shinoda & Funaki (2019) call an "unstructured bargaining" protocol. That is, at any time during a negotiation, each player is free to propose or approve a coalition that includes her 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 that coalition and the associated allocation among them. For example, at the beginning of a negotiation when all four players remain in the game, player 1 can propose {1,2}, {1,3}, {1,4}, {1,2,3}, {1,2,4}, {1,3,4}, or {1,2,3,4}. Note that a single-player coalition is not considered here, as it is the default outcome for the player when she ends the game without belonging to any coalition. Instead of proposing a coalition, a player can also approve a coalition that includes her and has been 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, the player has to withdraw 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 her approval.

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

4. Results

The new experiments on semi-structured mechanisms were 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 had not previously participated in similar experiments were recruited as subjects. The experiment was computerized with z-Tree (Fischbacher, 2007), and participants were recruited using ORSEE (Greiner, 2015). The previous experiments on structured mechanisms presented in Chessa et al. (2023b) were conducted under identical conditions in January and February 2019 (Winter mechanism) and January and February 2022 (H-MC

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mechanism). They involved a total of 176 students. See Table 6 for the number of participants and the mean duration and mean payment in each treatment.

In both the structured and the semi-structured bargaining procedures, at the end of each experiment, two rounds (one from the first four rounds and another from the last four rounds) were randomly selected for payments. Participants received cash rewards based on the points they earned in these two selected rounds at an exchange rate of 20 JPY = 1 point, in addition to the 1,500 JPY participation fee. The experiments lasted on average around 90 minutes for semi-structured mechanisms and around 100 to 105 minutes for structured mechanisms, including the instructions, comprehension quiz, and payment. Participants received a copy of the instruction slides, and a pre-recorded instruction video was played. The comprehension quiz was given on the computer screen after the explanation of the game. The user interface was explained during the practice rounds and referred to the handout about the computer screen. See Online Appendix A for English translations of the instruction materials and the comprehension quiz for both experiments.

Table 7 summarizes the duration of a negotiation, the frequency of complete breakdown (no coalition being formed), the number of offers or demands made within a negotiation, the number of messages sent during a negotiation (in treatments with chat), and the time until the first coalition was formed in the semi-structured experiments.[5] Equivalent results for structured experiments are not reported here because they are not relevant, given the limited freedom for negotiation.

Observe that the average duration of a negotiation is significantly longer in the offer-based than in the demand-based bargaining procedures.[6] The possibility of chat does not significantly affect the duration of the negotiation.[7] Note that while more messages are sent under the offer-based than the demand-based bargaining procedures when chat is possible, the difference is not statistically significant.[8] The complete failure of the negotiation is more frequently observed under the offer-based than the demand-based bargaining procedures,[9] while the possibility of chat does not significantly affect the failure rate.[10]

The longer duration of a negotiation under the offer-based bargaining procedure is not just because there are more groups in which negotiation failed completely. Even among those groups where a coalition was formed, the negotiation took longer under the offer-based than the demand-based bargaining procedures.[11] The same is true for the time that elapsed before the first coalition was formed.[12]

The number of proposals made under the offer-based bargaining procedures is significantly smaller than the number of demands made under the demand-based bargaining procedures.[13] The possibility of chat significantly reduces the number of offers or demands made.[14] The number of both demands and offers is, however, larger than what was allowed under Winter and H-MC (with a maximum of four) considered in Chessa et al. (2023b). It is not unexpected that this difference in the number of demands or offers between the structured and semi-structured bargaining procedures would affect the outcomes.

[5]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 statistic of interest in group i, ONC_i, OC_i, DNC_i, and DC_i are dummy variables that take a value of one if the treatment is offer-based no chat (ONC), offer-based with chat (OC), demand-based no chat (DNC), or demand-based with chat (DC), respectively and zero otherwise. Standard errors are corrected for within-session clustering effects. The statistical tests are based on the Wald test for the equality of the estimated coefficients of treatment dummies.

[6]$p = .0019$ and $p < .0001$ for without chat and with chat, respectively (Wald test).

[7]$p = .207$ and $p = .690$ for the demand-based and the offer-based bargaining procedures, respectively (Wald test).

[8]$p = .1200$ and $p = .1619$ with and without greeting messages, respectively (Wald test).

[9]$p = .0166$ and $p = .0013$ without chat and with chat, respectively (Wald test).

[10]$p = .3834$ and $p = .6701$ demand-based and offer-based bargaining procedures, respectively (Wald test).

[11]$p = .0016$ and $p = .0011$ without chat and with chat, respectively (Wald test).

[12]$p = .0008$ and $p = .0008$ without chat and with chat, respectively (Wald test).

[13]$p < .0001$ and $p < .0001$ without chat and with chat, respectively (Wald test).

[14]$p = .030$ and $p = .0001$ for the demand-based and the offer-based bargaining procedure, respectively (Wald test).

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Table 6. 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	88	1h34m	2810 JPY	May–June 2022
Without chat (No chat)	(24x2 + 20x2)			
Demand-based	84	1h22m	2860 JPY	May–June 2022
With chat (chat)	(24x2,16,20)			
Offer-based	88	1h36m	2810 JPY	June–July 2021
Without chat (No chat)	(24x2 + 20x2)			
Offer-based	84	1h36m	2900 JPY	June–July 2021
With chat (chat)	(20x3 + 24x1)			
Winter	96	1h40m	2650 JPY	January–February 2019
	(24x4)			
H-MC	80	1h45m	2850 JPY	January–February 2022
	(24, 20x2, 16)			

We now turn to analyzing the outcomes of our experiments. Section 4.1 focuses on grand coalition formation and the efficiency of the final outcome. Section 4.2 delves into the negotiation dynamics; that is, whether demands and offers evolved during the negotiation and whether and how they affected the final outcome.[15]

4.1. Grand coalition formation and efficiency

For our four games, the structured mechanisms 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, after which we compare these outcomes with the results from the experiments on the structured bargaining mechanisms reported in Chessa et al. (2023b).

4.1.1. Grand coalition formation

Table 8 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 showed a high level of cooperation.

On one hand, in games 1, 3, and 4, the grand coalition is the most frequently formed under semi-structured bargaining procedures, regardless of whether it is demand-based or offer-based and with or without chat. That is also the case under structured Winter and H-MC mechanisms, except for the 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 bargaining procedures.

In Figure 2, we show the results 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

[15]For completeness and a more exhaustive comparison with the results presented in Chessa et al. (2023b), we report additional analyses in Online Appendix C.

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Table 7. Summary statistics of semi-structured bargaining experiments

Treatment	Duration[1]	Frequency of complete failure	Number of offers or demands[1]	Number of messages[2]	Number of non-greeting messages	Duration[3]	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	96.9	0.018	6.31	2.03	1.69	92.59	80.50
With chat (chat)	(8.64)	(0.01)	(0.33)	(0.69)	(0.71)	(9.03)	(11.46)
Offer-based	185.33	0.131	4.88			163.94	152.55
Without chat (No chat)	(9.73)	(0.013)	(0.24)			(10.14)	(11.47)
Offer-based	179.23	0.119	3.33	4.68	3.16	159.79	156.23
With chat (chat)	(11.42)	(0.024)	(0.13)	(1.33)	(0.62)	(13.23)	(13.97)
Num. obs.	688	688	688	336	336	634	634
R^2	0.675	0.108	0.773	0.403	0.312	0.656	0.657

Note: Standard errors are corrected for session-level clustering effects and shown in parentheses.
1: Includes those groups that did not form any coalition and were thus terminated upon reaching the maximum duration.
2: Includes greeting messages.
3: Does not include groups that did not form any coalitions.

Table 8. Frequencies of coalitions being formed

Game 1						
	Demand-based			Offer-based		
Coalition Game 1	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						
{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						
{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						
{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

coalition without the null player in game 2 ({2,3,4}) as a grand coalition. The horizontal lines with indications of Winter and H-MC are the experimental results of these two structured procedures reported in Chessa et al. (2023b).[16]

[16]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 a value of one if the grand coalition is formed and zero otherwise. The equation is presented for group *i*. $Winter_i$, and $H - MC_i$ are dummy variables that take a value of one if the treatment is Winter, and H-MC, respectively, and zero otherwise. Other treatment dummies are the same as

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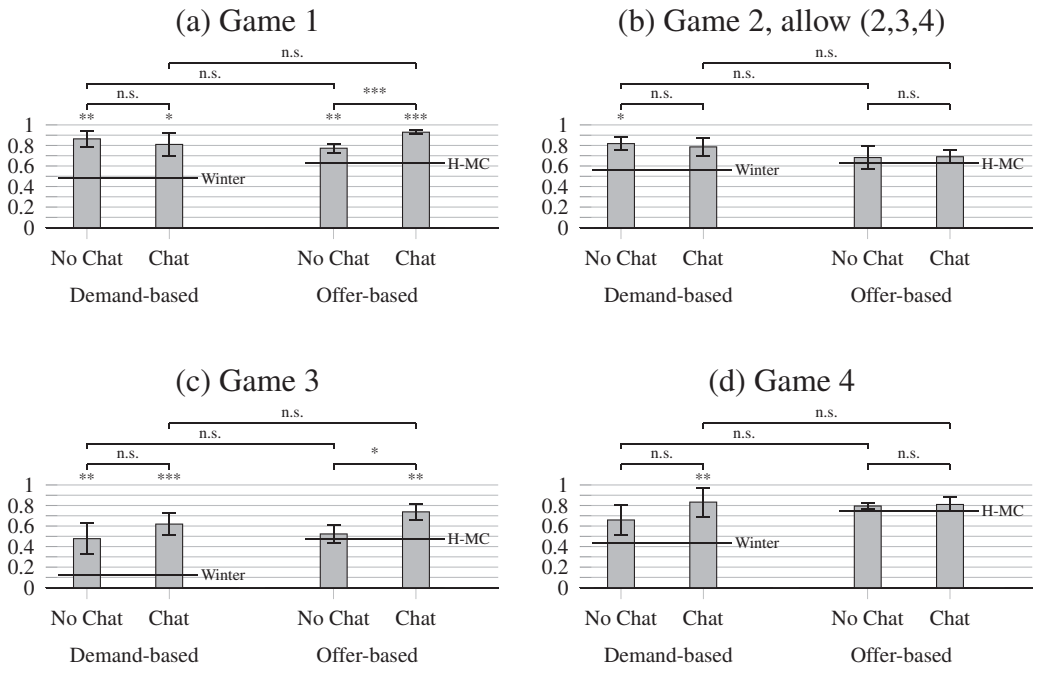


Fig. 2 Proportion of times the grand coalition formed

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

We observe that the grand coalition is formed more frequently under the semi-structured bargaining procedures than under the structured bargaining procedures, for both demand-based and offer-based bargaining 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 bargaining procedures. For the demand-based procedures, the grand coalition is more frequently formed under the semi-structured ones than the structured approach, significantly so when chat is not allowed in game 2 and when chat is allowed in game 4. Among semi-structured bargaining procedures, there are cases where chat significantly facilitates the formation of the grand coalition (games 1 and 3 for the offer-based procedure). Conditional on whether free from chat is possible, we do not observe significant differences between the demand-based and the offer-based semi-structured bargaining procedures in any of the four games.

4.1.2. Efficiency

Figure 3 shows the efficiency across treatments in each game. Efficiency is computed as the share of the sum of the points obtained by four players relative to the worth of the grand coalition.[17]

Because efficiency is higher when the grand coalition is formed more frequently, the results are similar to the frequencies of the grand coalition formation discussed above. However, it is important to note 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 for both

the one explained above. The standard errors are corrected for within-session clustering effects. The statistical tests are based on the Wald test for the equality of the estimated coefficients of treatment dummies.

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

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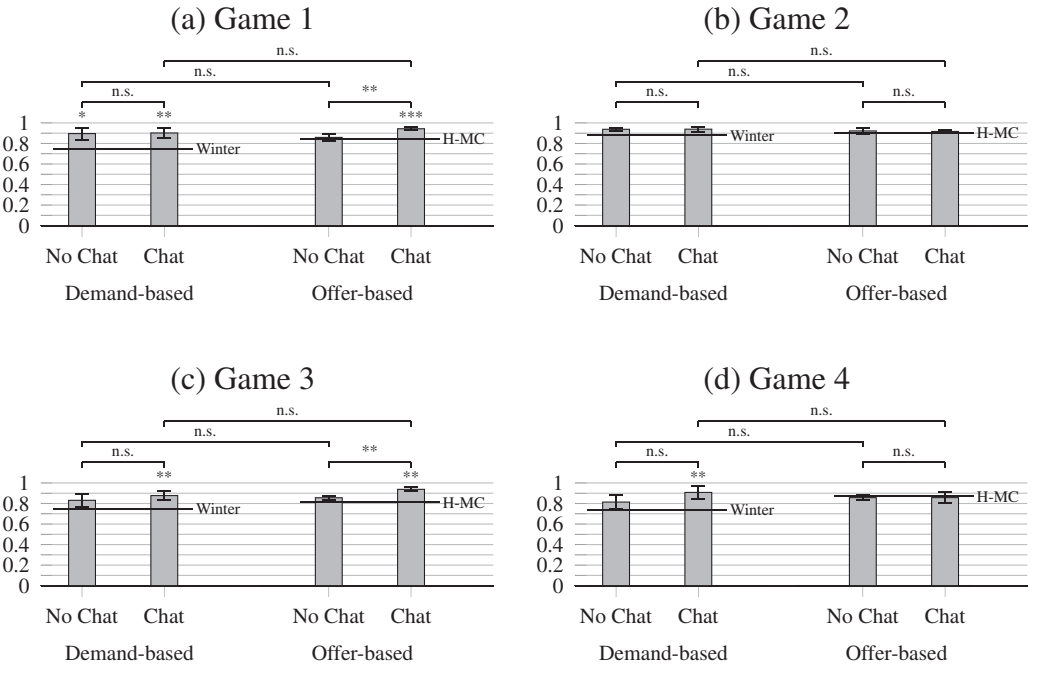


Fig. 3 Efficiency

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

demand- and offer-based approaches, under the semi-structured bargaining procedure with chat than under the structured bargaining 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 bargaining procedures, in case of the demand-based bargaining procedure, it is higher under semi-structured than the structured bargaining procedure with chat in game 4.

We summarize the results of this section by stating that our experiments confirm the overall superior performance in terms of grand coalition formation and efficiency of semi-structured mechanisms than their structured counterparts.

4.2. Negotiation dynamics

We have already noted that the number of offers and demands made in the semi-structured bargaining procedures are larger than were permitted by construction in the Winter and H-MC mechanisms. In this subsection, we analyze the content of these offers and demands to better understand how they evolved during the negotiation and whether and how they affected the final outcome.[18]

4.2.1. Two examples of negotiation dynamics

We start by providing two specific examples of negotiation dynamics in semi-structured mechanisms, one for offer-based and the other for demand-based bargaining procedure without chat. These examples may help identify the possible advantage of semi-structured mechanisms over structured ones.

[18]It should be noted that our data is incomplete in that while all the offers and demands and their cancellations are recorded, only the most recent approval and withdrawal of approval by each player, and not any intermediate ones, are recorded.

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Table 9. An example of the dynamics of negotiation in game 1 of the offer-based semi-structured bargaining procedure without chat

Time	Player	Coali.	x_1	x_2	x_3	x_4	Dist.SV	Dist.ED	Eff.	Outcome	Out.time
22.562	4	1234	25	25	23	27	4.73	2.83	1	Cancel	120.75
112.25	3	1234	20	25	25	30	2.76	7.07	1	Cancel	206.78
161.2	2	1234	25	30	25	20	12.56	7.07	1	Cancel	192.3
198.63	2	1234	25	25	25	25	6.41	0	1	Approve	235.14

Table 9 shows an example of the dynamics of the proposals made in game 1 of the offer-based semi-structured bargaining procedure without chat. "Time" and "Player" represent when and by whom an offer was made; "Coali." and "x_j" ($j \in \{1, 2, 3, 4\}$) correspond to the proposed coalition and the allocation within it; "Dist.SV", "Dist.ED", and "Eff." are the distance of the proposed allocation from the Shapley value, the distance from the equal division, and the efficiency of the offer, respectively.[19] "Outcome" and "Out.time" show the eventual outcome and the timing of the offer.

In this group, all the offers involved the grand coalition, but the allocation within the coalition differed. First, player 4 made an offer giving themselves slightly higher payoff than the others while reducing the payoff of player 3. Later, player 3 made a counteroffer by reducing player 1's payoff while increasing their own as well as player 4's payoff compared to the proposal by the player 4. This counteroffer was closer to the Shapley value and further away from the equal division than the offer made by player 4. Seeing this counteroffer, player 4 canceled their offer. Later, player 2 made a counteroffer to that of player 3 by reducing the payoff for player 4 while increasing their own and player 1's payoff and maintaining the payoff for player 3. This offer was further away from the Shapley value than player 3's existing offer while the distance from the equal division was the same. Eventually, player 2 canceled this offer and made an offer that split the pie equally among four players. This offer was eventually approved by everyone.

Table 10 shows an example of the dynamics of the demands made in game 1 of the demand-based semi-structured bargaining procedure without chat. The columns are similar to those in Table 9. "No.Act." and "No.Dem." represent the number of active players and the number of demands submitted at the time, respectively; "Dist.SV", "Dist.ED", and "Eff." are computed only when four demands are submitted; "Outcome" shows the coalition being formed. The specific demands made by the players are shown in bold. The cancellation of an existing demand is recorded as demanding 0.

In this group that eventually formed the grand coalition, there were three instances where four demands were all on the table. Among these instances, we observe increasing efficiency and a corresponding decline in the distance to the Shapley value and the equal division over time. In the end, although it was possible for some players to demand a few more points, they decided to stop the negotiation.

In these two examples, in many instances, some improvements, in terms of either the efficiency or the distance from the Shapley value or the equal division, were observed during the negotiation. Note that in the corresponding structured bargaining procedures, such within-negotiation improvements are not possible by design.

We now analyze the differences across treatments more systematically by first looking at the properties of the first offers (the offer-based case) or the first instances in which the demands from all four

[19] Dist.SV $= \sum_j \sqrt{(x_j - sv_j)^2}$, where sv_j is the Shapley value for j in the corresponding game. Dist.ED $= \sum_j \sqrt{(x_j - ed)^2}$ where $ed = 25$ in games 1 and 2, and $ed = 50$ in games 3 and 4. For game 2, when coalition {2,3,4} is formed, Dist.ED $= \sum_{j \neq 1} \sqrt{(x_j - 100/3)^2}$

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Table 10. An example of the dynamics of negotiation in game 1 of the demand-based semi-structured bargaining procedure without chat

Time	No.Act.	Player	No.Dem.	x_1	x_2	x_3	x_4	Dist.SV	Dist.ED	Eff.	Outcome
7.13	4	2	1	0	**10**	0	0				
7.72	4	3	2	0	10	**25**	0				
9.15	4	1	3	**10**	10	25	0				
10.72	4	4	4	10	10	25	**27**	18.66	21.31	0.72	
15.25	4	2	3	10	**0**	25	27				
29.86	4	2	4	10	**25**	25	27	12.68	15.13	0.87	
31.67	4	1	3	**0**	25	25	27				
41.52	4	1	4	**20**	25	25	27	4.38	5.39	0.97	1234

players are on the table (the demand-based case) and their likelihood of approval. We then complement these analyses by investigating the relationships between properties of all the offers or the set of four demands and their likelihood of resulting in the grand coalition formation.

4.2.2. First offers and demands versus all offers and demands and the grand coalition formation

Tables B.1 and B.2 in Online Appendix B report the average (and standard deviation) of the characteristics of the first set of four demands (for demand-based bargaining procedures) and the offers (for offer-based bargaining procedures) in our four games.

From a careful observation of these tables, we can highlight the two key results of this analysis (which we do not report in full here for simplicity). Focusing on offer-based mechanisms, we observe that the grand coalition is formed less frequently based on the first offer in semi-structured bargaining procedures when compared to H-MC. As a result, efficiency is also lower. Similarly, for demand-based mechanisms, the likelihood that the grand coalition is formed based on the first instance in which all players made their demand is lower in semi-structured bargaining procedures than in Winter (except for game 3).

These results confirm what was previously hypothesized, namely that the better performance of semi-structured mechanisms is a consequence of the ability to adjust offers and demands. In fact, this improved performance is not observed at the very beginning but only at the end of the negotiation. To conclude, we now ask in which direction these offers and demands should be adjusted by investigating which characteristics of the proposed allocations more easily lead to an agreement.

Table 11 shows the results of linear regressions where the dependent variable is whether the grand coalition (including $\{2, 3, 4\}$ in game 2) is formed ($= 1$) or not ($= 0$), and independent variables are the characteristics of the set of demands or offers. We focus only on those sets of demands or offers where the formation of the grand coalition is possible (that is, it involves all the members of the grand coalition and is feasible).

We see that the "Dist.ED" (the distance to the equal division solution) is negatively correlated with grand coalition formation in both demand-based and offer-based semi-structured bargaining procedures. This suggests, as we have seen above through examples, that the dynamics of negotiation tend to favor allocations that are closer to the equal division under semi-structured bargaining. "Dist.SV" (the distance to the Shapley value) is also negatively correlated with the formation of the grand coalition in both Winter and H-MC, as well as in the two offer-based semi-structured bargaining procedures. In the demand-based semi-structured approach with chat, "Dist.SV" is instead positively correlated with the formation of the grand coalition. However, its magnitude is only about half of the effect of "Dist.ED". Finally, efficiency is positively correlated with the formation of the grand coalition in all the demand-based bargaining procedures.

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Table 11. Characteristics of the sets of demands (for demand-based procedures) and the offers (for offer-based procedures) and grand coalition formation

	Demand-based			Offer-based		
	No chat	Chat	Winter	No chat	Chat	H-MC
Dist.SV	-0.0002	0.0059**	-0.0116*	-0.0052***	-0.0061***	-0.008***
	(0.0033)	(0.0026)	(0.006)	(0.0013)	(0.0018)	(0.0024)
Dist.ED	-0.0072**	-0.0108***	0.0023	-0.0029**	-0.0084***	-0.0035
	(0.0031)	(0.0022)	(0.0054)	(0.0013)	(0.0015)	(0.0027)
Eff.	1.314***	1.535***	1.435***			
	(0.342)	(0.315)	(0.351)			
Cons.	-0.712**	-0.866***	-0.45	0.302***	0.497***	0.828***
	(0.355)	(0.327)	(0.37)	(0.03)	(0.04)	(0.053)
N	298	245	112	662	442	158
R^2	0.141	0.304	0.372	0.04	0.093	0.157

Note. Dependent variable is whether the grand coalition is formed (= 1) or not (= 0); linear probability model pooling data from the games; standard errors are clustered at the group (negotiation) level and reported in parentheses. *, **, and *** show statistical significance at the 10%, 5%, and 1% levels, respectively.

To summarize these results, we observe that proposals closer to equal division, closer to the Shapley value, and with greater efficiency are more likely to be accepted, thus facilitating the formation of the grand coalition. By design, semi-structured mechanisms provide more opportunities to adjust proposals in this direction, leading to better final outcomes in terms of coalition formation and overall efficiency.

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). The present study seeks to contribute to this body of literature by experimentally comparing the outcomes of structured versus semi-structured bargaining procedures in the context of coalition formation. 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 & 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 than did structured procedures. This outcome occurs because participants in the former could explore a wider range of proposals and demands during negotiations, allowing them to adjust their offers toward proposals that are more likely to be accepted. A deeper analysis reveals that semi-structured bargaining procedures do not necessarily yield better outcomes when considering only the initial set of offers and demands. Instead, their advantage over structured bargaining procedures becomes evident toward the end of the negotiation process. Structured bargaining procedures, while theoretically predicted to lead to the formation of the grand coalition, result instead in an a posteriori expected payoff distribution that heavily favors randomly selected first movers at the expense of players who intervene later. These unfair proposals

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are often rejected, and structured mechanisms do not allow for adjustments, ultimately limiting their effectiveness.

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 the frequency of grand coalition formation and efficiency, no significant differences between the demand-based and offer-based semi-structured bargaining procedures arose in these dimensions. 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 when and how often they can act, the outcomes of the negotiations become similar regardless of whether the bargaining procedure is an offer-based or a demand-based one. Even though the possibility of communicating through free-form chat does not play a substantial role, it has been shown in some cases to facilitate better outcomes.

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 and having the possibility of freely adjusting during the negotiation 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. First, in our experiment we used only the four games considered by Chessa et al. (2022, 2023a, 2023b) in order to make a direct comparison with previous experimental investigations. As an initial step, future studies should consider more varieties of games (non-superadditive, non-convex, those with more than four players, or more general games such as partition function games (Thrall & Lucas, 1963)) to better understand the possible impacts of various behavioral biases, such as fairness consideration and loss aversion, in advancing the Nash program while incorporating the fruits of advances in behavioral and experimental economics. Testing our unstructured and semi-structured mechanisms for a wider range of games can confirm or call into question the results of this paper.

But we believe that the most challenging direction for future investigations is to explore whether alternative structured mechanisms can be designed to outperform semi-structured mechanisms, as observed in many other markets (see the numerous examples presented in the Introduction). It is in fact important to stress that in many situations, rigorous structured mechanisms may be especially useful or even necessary. This is the case, for example, when unstructured or semi-structured bargaining is not feasible, either because players are dispersed or because they do not even know whom they are playing against, as for example in financial markets.

A natural approach would be to define and/or test mechanisms whose theoretical predictions lead to a fairer payoff distribution, not only a priori but also a posteriori, that is, given the specific implementation of the game. In this regard, it is important to note that Chessa et al. (2022) experimentally tested the bargaining mechanism proposed by Pérez-Castrillo & Wettstein (2001). This mechanism, despite predicting exactly the Shapley value at equilibrium, was found to perform even worse than H-MC, further amplifying the first-mover advantage. But this negative result was likely due to the complexity of the mechanism, and to the difficulty of the experimental subjects in understanding its dynamics. An alternative and simpler way to test a different algorithm would be to implement a mechanism à la Winter, where players are required to play following all possible orders, or à la H-MC, where all players take turns acting as the first mover. However, while this approach could be promising, it would lead to a much longer experiment in which additional factors would need to be carefully controlled, such as the order of the different sequences itself.

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References

Abe, T., Funaki, Y., & Shinoda, T. (2021). Invitation games: An experimental approach to coalition formation. *Games*, *12*(3), 64.

Brosig, J., Weimann, J., & Yang, C.-L. (2003). The hot versus cold effect in a simple bargaining experiment. *Experimental Economics*, *6*(1), 75–90.

Chen, Y., & Sönmez, T. (2006). School choice: An experimental study. *Journal of Economic Theory*, *127*(1), 202–231.

Chessa, M., Hanaki, N., Lardon, A., & Yamada, T. (2022). The effect of choosing a proposer through a bidding procedure in implementing the Shapley value. *Journal of Economic Psychology*, *93*, 102568.

Chessa, M., Hanaki, N., Lardon, A., & Yamada, T. (2023a). An experiment on demand commitment bargaining. *Dynamic Games and Applications*, *13*(2), 589–609.

Chessa, M., Hanaki, N., Lardon, A., & Yamada, T. (2023b). An experiment on the Nash program: A comparison of two strategic mechanisms implementing the Shapley value. *Games and Economic Behavior*, *141*, 88–104.

Coles, P., Cawley, J., Levine, P. B., Niederle, M., Roth, A. E., & Siegfried, J. J. (2010). The job market for new economists: A market design perspective. *Journal of Economic Perspectives*, *24*(4), 187–206.

Cox, J. C., Smith, V. L., & Walker, J. M. (1988). Theory and individual behavior of first-price auctions. *Journal of Risk and Uncertainty*, *1*(1), 61–99.

Cramton, P. (2017). Electricity market design. *Oxford Review of Economic Policy*, *33*(4), 589–612.

Crawford, V. P. (1982). A theory of disagreement in bargaining. *Econometrica*, *50*(3), 607–637.

Dang, V. D., Dash, R. K., Rogers, A., & Jennings, N. R. (2006). Overlapping coalition formation for efficient data fusion in multi-sensor networks, *Proceedings of the 21st national conference on artificial intelligence (AAAI-06)* Vol. 6, pp. 635–640. Association for the Advancement of Artificial Intelligence.

Denton, M. J., Rassenti, S. J., & Smith, V. L. (2001). Spot market mechanism design and competitivity issues in electric power. *Journal of Economic Behavior & Organization*, *44*(4), 435–453.

Dickerson, J. P., Procaccia, A. D., & Sandholm, T. (2012). Optimizing kidney exchange with transplant chains: Theory and reality. *Proceedings of the 11th International conference on autonomous agents and multiagent systems 2*, 711–718.

Duffy, J., Lebeau, L., & Puzzello, D. (2025). Bargaining under liquidity constraints: Experimental evidence *Journal of Economic Theory,* 228 106035.

Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*(2), 171–178.

Friedman, M. (2016). Capitalism and freedom, In R. Blaug, & J. Schwarzmantel (Eds.), *Democracy: A reader*. (pp. 344–349) Columbia University Press

Gamson, W. A. (1961). A theory of coalition formation. *American Sociological Review*, *26*(3), 373–382.

Greiner, B. (2015). An online recruitment system for economic experiments. *Journal of the Economic Science Association*, *1*(1), 114–125.

Güth, W. (2012). Bargaining and negotiations: What should experimentalists explore more thoroughly? In R. Croson, & G. E. Bolton (Eds.), *The Oxford handbook of economic conflict resolution*. (241–253) Oxford University Press.

Hart, S., & Mas-Colell, A. (1996). Bargaining and value. *Econometrica*, *64*(2), 357–380.

Holler, M. J. (1982). Forming coalitions and measuring voting power. *Political Studies*, *30*(2), 262–271.

Kagel, J. H., & Levin, D. (1986). The winner's curse and public information in common value auctions. *American Economic Review*, *76*(5), 894–920.

Kagel, J. H., & Roth, A. E. (2000). The dynamics of reorganization in matching markets: A laboratory experiment motivated by a natural experiment. *The Quarterly Journal of Economics*, *115*(1), 201–235.

Kahan, J. P., & Rapoport, A. (1980a). Coalition formation in the triad when two are weak and one is strong. *Mathematical Social Sciences*, *1*(1), 11–37.

Kahan, J. P., & Rapoport, A. (2014). *Theories of Coalition formation*. Psychology Press.

https://doi.org/10.1017/eec.2025.10032 Published online by Cambridge University Press

Karagözoğlu, E. (2019). On "going unstructured" In bargaining experiments, In J.-F. Laslier, H. Moulin, M. R. Sanver, & W. S. Zwicker (Eds.) *The future of economic design: The continuing development of a field as envisioned by its researchers* (295–304). Springer International Publishing.
Komorita, S. S., & Kravitz, D. A. (1983). Coalition formation: A social psychological approach. In P. B. Paulus (Ed.), *Basic group processes* (179–203). Springer.
Konishi, H., & Ray, D. (2003). Coalition formation as a dynamic process. *Journal of Economic Theory*, *110*(1), 1–41.
Milgrom, P. R., & Weber, R. J. (1982b). A theory of auctions and competitive bidding. *Econometrica: Journal of the Econometric Society*, *50*(5), 1089–1122.
Milgrom, P., & Weber, R. J. (1982a). The value of information in a sealed-bid auction. *Journal of Mathematical Economics*, *10*(1), 105–114.
Nash, J. F. (1953). Two-person coooperative games. *Econometrica*, *21*(1), 128–140.
Okada, A., & Riedl, A. (2005). Inefficiency and social exclusion in a coalition formation game: Experimental evidence. *Games and Economic Behavior*, *50*(2), 278–311.
Pérez-Castrillo, D., & Wettstein, D. (2001). Bidding for the surplus : A non-cooperative approach to the Shapley value. *Journal of Economic Theory*, *100*(2), 274–294.
Rapoport, A., & Kahan, J. P. (1984). Coalition formation in a five-person market game. *Management Science*, *30*(3), 326–343.
Roth, A. E. (1985). The college admissions problem is not equivalent to the marriage problem. *Journal of Economic Theory*, *36*(2), 277–288.
Roth, A. E. (2002). The economist as engineer: Game theory, experimentation, and computation as tools for design economics. *Econometrica*, *70*(4), 1341–1378.
Roth, A. E., & Peranson, E. (1999). The redesign of the matching market for American physicians: Some engineering aspects of economic design. *American Economic Review*, *89*(4), 748–780.
Roth, A. E., Sönmez, T., & Ünver, M. U. (2004). Kidney exchange. *The Quarterly Journal of Economics*, *119*(2), 457–488.
Roth, A. E., Sönmez, T., & Ünver, M. U. (2007). Efficient kidney exchange: Coincidence of wants in markets with compatibility-based preferences. *American Economic Review*, *97*(3), 828–851.
Rothschild, E. (1994). Adam Smith and the invisible hand. *The American Economic Review*, *84*(2), 319–322.
Serrano, R. (2005). Fifty years of the Nash program, 1953–2003. *Investigaciones Economicas*, *29*(2), 219–258.
Serrano, R. (2008). Nash Program. In S. Durlauf, & L. Blume (Eds.), *The new Palgrave dictionary of economics* (2nd ed.). McMillan.
Serrano, R. (2014). The Nash program: A broader interpretation. *Ensayos*, *33*(2), 105–106.
Serrano, R. (2021). Sixty-Seven years of the Nash Program: Time for retirement?. *SERIEs*, *12*(1), 35–48.
Shapley, L. S. (1953). A value for n-person games. In H. Kuhn, & A. Tucker (Eds.) *Contribution to the theory of games*. (Vol. II, 303–317). Princeton University Press.
Shapley, L. S., & Shubik, M. (1969). Pure competition, coalitional power, and fair division. *International Economic Review*, *10*(3), 337–362.
Shinoda, T., & Funaki, Y. (2019). Unstructured bargaining experiment on three-person cooperative games Working Paper 1915, Waseda University.
Smith, V. L. (1967). Experimental studies of discrimination versus competition in sealed-bid auction markets. *The Journal of Business*, *40*(1), 56–84.
Stevenson, W. B., Pearce, J. L., & Porter, L. W. (1985). The concept of "coalition" in organization theory and research. *Academy of Management Review*, *10*(2), 256–268.
Thrall, R. M., & Lucas, W. F. (1963). N-person games in partition function form. *Naval Research Logistics Quarterly*, *10*(1), 281–298.
Vickrey, W. (1961). Counterspeculation, auctions, and competitive sealed tenders. *The Journal of Finance*, *16*(1), 8–37.
von Neumann, J. (1928). Zur theorie der gesellschaftsspiel. *Matematische Annalen*, *100*(1), 295–320.
von Neumann, J., & Morgenstern, O. (1944). *Theory of games and economic behavior*. Princeton University Press.
Wilson, R. (2002). Architecture of power markets. *Econometrica*, *70*(4), 1299–1340.
Winter, E. (1994). The Demand Commitment Bargaining and Snowballing Cooperation. *Economic Theory*, *4*(4), 255–273.

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