Discussion Paper No. 1152
ISSN (Print) 0473-453X
ISSN (Online) 2435-0982

AN EXPERIMENT ON DEMAND COMMITMENT BARGAINING

Michela Chessa
Nobuyuki Hanaki
Aymeric Lardon
Takashi Yamada

Revised June 2022
December 2021

The Institute of Social and Economic Research
Osaka University
6-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan

An experiment on demand commitment bargaining

Michela Chessa* Nobuyuki Hanaki† Aymeric Lardon‡
Takashi Yamada§

June 27, 2022

Abstract

In this experiment, we compare three implementations of the *Winter demand commitment bargaining mechanism*: a one-period implementation, a two-period implementation with low delay costs, and a two-period implementation with high delay costs. Despite the different theoretical predictions, our results show that the three different implementations result in similar outcomes in all our investigation domains: namely, coalition formation, alignment with the Shapley value prediction, and satisfaction of the axioms. Our results suggest that a lighter bargaining implementation with only one period is often sufficient in providing allocations that sustain the Shapley value as an appropriate cooperative solution concept, while saving unnecessary time and resource costs.

JEL code: C71, C72, C90, D82

Keywords: Nash program, Shapley value, Experiments, Winter mechanism

*Université Côte d'Azur, CNRS, GREDEG, France. E-mail: michela.chessa@univ-cotedazur.fr
†Institute of Social and Economic Research, Osaka University, Japan. E-mail: nobuyuki.hanaki@iser.osaka-u.ac.jp
‡GATE Lyon Saint-Etienne, UMR 5824 CNRS, Université de Lyon. France. E-mail: aymeric.lardon@univ-st-etienne.fr
§Yamaguchi University, Japan. E-mail: tyamada@yamaguchi-u.ac.jp

1 Introduction

The aim of the *Nash program* (Nash, 1953) is to provide a noncooperative foundation of cooperative solution concepts. The Nash program has a long history, having commenced with Nash, who designed a noncooperative game that sustained the Nash solution of his cooperative *bargaining problem* as the equilibrium (Nash, 1950). Since his seminal paper, the Nash program has continued to grow, with many theoretical and experimental contributions (For an exhaustive literature review, we refer readers to Serrano, 2005, 2008, 2014, 2021). To cite the first of the aforementioned surveys, and the words of Nash himself, "*The idea [of the Nash program] is both simple and important: the relevance of a concept [...] is enhanced if one arrives at it from different points of view*" (Serrano, 2005, p. 220). In fact, "*it is rather significant that this different approach yields the same solution. This indicates that the solution is appropriate for a wider variety of situations*" (Nash, 1953, p. 136).

Most papers that contribute to the Nash program are devoted to sustaining the noncooperative foundation of the Shapley value solution (Shapley, 1953) (see, among others, Gul, 1989; Harsanyi, 1981; Hart and Moore, 1990; Krishna and Serrano, 1995; Winter, 1994; Hart and Mas-Colell, 1996; Perez-Castrillo and Wettstein, 2001). Because of its intuitive and desirable properties, the Shapley value has been applied to a variety of situations, such as cost or payoff sharing, voting power, fair division, as well as, most recently, to many noneconomic contexts, including machine learning, artificial intelligence models, and data analysis (e.g., in one unusual application, the Shapley value solution was implemented to obtain information about gene expression resulting from microarray games (Lucchetti et al., 2010)). As a result, the Shapley value is currently the most widely used axiomatic cooperative solution concept, the appropriateness of which is validated by its many applications and an extensive literature listing its appealing theoretical properties.

In Chessa et al. (2022), we aimed to contribute to the Nash program in sustaining the Shapley value by providing a comparison between the experimental results of a demand-based mechanism (a simple one-period version of Winter (1994) model) versus an offer-based (*à la* Hart and Mas-Colell (1996)) mechanism. Our analysis showed that the Winter mechanism (namely, the *Winter demand commitment bargaining mechanism*) better provides allocations that reflect players' effective bargaining power and satisfy the axioms that characterize the Shapley value. Conversely, the efficiency and frequency of grand coalition formation are not very high. This finding suggests that the Shapley value is indeed an appealing solution in all such situations in which some bargaining agents interact by expressing their demands about the share that they wish to obtain from cooperation. This is a key point when highlighting players' effective bargaining power.

However, real-world applications of demand-based bargaining processes may provide the players more time to reach an agreement than one period. Having more time for agreeing is often costly (obviously in terms of time, but often also in terms of resources), but whether it is more (or less) effective is an open question. Therefore, a simple one-period version of the Winter model may not be suitable to capture all these nuances of the problem. Thus, in this paper, our main research question is to investigate the robustness of the performances of the Winter mechanism when departing from its simplified version. In fact, we affirm that for a solution—in our case the Shapley value—to be relevant, players must agree on it when interacting under different rules. First, we compare the previously studied one-period (1p) implementation versus a two-period (2p) implementation. In the one-period implementation, each player, one after another, becomes a proposer and makes a demand concerning the payoff that they are willing to receive from a possible collaboration. If and when at some point a compatible demand is introduced, which means that a coalition exists for which the total demands do not exceed the worth of the coalition, this coalition forms, leaves the game, and the bargaining continues with the rest of the players, until there is at least one player remaining who needs to submit a demand. Players with unsatisfied demands at the end of the first period obtain their individual value in the one-period version of the model. In the two-period implementation, if some players are left with unsatisfied demands after the first period, they have a second chance to cooperate because the bargaining procedure repeats for a second time with this set of players by canceling their previous demands and charging them a fixed delay cost. Second, we compare the performances of the Winter mechanism in its two-period implementation when implementing *low* (2pL) versus *high* (2pH) delay costs.

The theoretical prediction expects all three implementations to provide complete cooperation in the first period and a power share close to the Shapley value (on average, as the *ex ante* equilibrium). However, the theoretical *ex post* equilibrium payoff differs between the different implementations, in particular in terms of the first-mover advantage, which is expected to be smaller in 2p implementations than in 1p implementations. However, as already observed by Fréchette et al. (2005), experiments often show that actual bargaining behavior is sometimes not as sensitive to the different bargaining rules as the theory suggests, and this is what happens in our case.

Our results show that the three different implementations of the Winter mechanism result in similar outcomes in all our investigation domains: namely, coalition formation, alignment with the theoretical prediction, and satisfaction of the axioms. Moreover, we observe comparable results when considering the outcome of the first period in a 2p implementation and the outcome of a game with a player who always has a zero marginal contribution to any coalition, a game that does not fully satisfy the theoretical assumptions of the model. We interpret this finding as a robustness of the Winter mechanism in sustaining the Shapley value. Moreover, these results support the implementation of the Shapley value as an appealing cooperative solution concept in many real-world applications, both when the decisions must be made rapidly, or when the time for bargaining is longer. Finally, we suggest that simpler and faster bargaining is often sufficient in providing allocations that sustain the Shapley value because a second chance to reach an agreement often proves to be ineffective in augmenting the chance of the players reaching an agreement, or in bringing them closer to the predicted allocation.

The rest of the paper is organized as follows. Section 2 presents the general definition and the properties of a cooperative transferable utility (TU) game, as well as the Shapley value and its axiomatizations. Section 3 presents the Winter mechanism and its main theoretical results. Section 4 describes the setting of our experiment and presents our hypotheses. The results are presented in Section 5. Section 6 concludes.

2 Theoretical model

2.1 Cooperative TU games and solutions

Let $N = \{1, \dots, n\}$ be a finite set of *players*. Each subset $S \subseteq N$ is called a *coalition* and N is called the *grand coalition*. A *cooperative TU game* (from now on, we refer to this simply as a *cooperative game*) consists of a couple (N, v), where N is the set of players and $v : 2^N \to \mathbb{R}$, with $v(\emptyset) = 0$, is the *characteristic function*, which assigns to each coalition $S \subseteq N$ the *worth* $v(S)$, that is, the worth that members of S can achieve by cooperation. If no ambiguity appears, we consider the set of players N to be fixed and we write v instead of (N, v). We denote with $\mathcal{G}^N$ the set of all games with player set N.

Players i and j are *symmetric* in $v \in \mathcal{G}^N$, if $v(S \cup \{i\}) = v(S \cup \{j\})$ for all $S \subseteq N \setminus \{i, j\}$. 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 said to be *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 $S, T \subseteq N$ (*strictly convex* if the inequality holds strictly). Another equivalent definition for convexity can be stated as $v(S \cup \{i\}) - v(S) \leq v(T \cup \{i\}) - v(T)$ for each $S \subseteq T \subseteq N \setminus \{i\}$. In (strictly) convex games, cooperation becomes increasingly appealing, leading to the formation of the grand coalition. We may observe that convexity $\Rightarrow$ superadditivity $\Rightarrow$ monotonicity.

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

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

that is, it contains all the allocations that are *efficient* ($x(N) = v(N)$) and *individually rational* ($x_i \geq v(\{i\}) \forall i \in N$).

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

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

An element of the core is stable in the sense that if such a vector is proposed as an allocation for the grand coalition, no coalition will have an incentive to split off and cooperate on its own. Intuitively, the idea behind the core is analogous to that behind a (strong) Nash equilibrium of a noncooperative game: an outcome is stable if no group deviation is profitable. For the Nash equilibrium, the possible deviation is for a single player, whereas in the core we speak about deviations of groups of players.

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 *Shapley value* is the most well-known solution concept, which is widely applied in economic models, and is 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 every player their expected marginal contribution to the coalition of players that entered before them given that every order of entrance has equal probability. This solution concept was defined as respecting some notion of fairness (see Section 2.2 for more discussion about its properties), but it is not necessarily stable. However, if the game is superadditive, the Shapley value is an imputation and, if the game is convex, it is the core barycenter (and then, in particular, it belongs to it).

In our analysis, we will consider an easier solution concept, the *equal division solution*, which distributes the worth $v(N)$ equally between the players. It is defined as:

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

Such a solution was investigated as an appealing solution for cooperating players when not considering the worth of the coalitions (see, e.g., de Clippel and Rozen, forthcoming).

2.2 Axiomatizations of the theoretical game solutions

In the literature, we find various axiomatic characterizations of the Shapley value. The first one is from Shapley (1953) and it involves efficiency, symmetry, additivity, and the null player. The characterization by Young (1985) involves efficiency, symmetry, and strong monotonicity, and the characterization by van den Brink (2002) involves efficiency, the null player, and fairness. We list these axioms in Table 1 (for a solution $\psi : \mathcal{G}^N \to \mathbb{R}^N$).

Table 1: The axioms

Axioms	
Efficiency	for every v in $\mathcal{G}^N$, $\sum_{i \in N} \psi_i(v) = v(N)$
Symmetry	if i and j are symmetric players in game $v \in \mathcal{G}^N$, then $\psi_i(v) = \psi_j(v)$
Additivity	for all $v, w \in \mathcal{G}^N$, $\psi(v + w) = \psi(v) + \psi(w)$
Homogeneity	for all $v \in \mathcal{G}^N$ and $a \in \mathbb{R}$, $\psi(av) = a\psi(v)$
Null player	if i is a null player in game $v \in \mathcal{G}^N$, then $\psi_i(v) = 0$
Strong monotonicity	if $i \in N$ is such that $v(S \cup \{i\}) - v(S) \leq w(S \cup \{i\}) - w(S)$ for each $S \subseteq N$, then $\psi_i(v) \leq \psi_i(w)$
Fairness	if i, j are symmetric in $w \in \mathcal{G}^N$, then $\psi_i(v + w) - \psi_i(v) = \psi_j(v + w) - \psi_j(v)$ for all $v \in \mathcal{G}^N$

3 The Winter mechanism

3.1 Description of the Winter mechanism

In our experiments, we implemented the bargaining model based on sequential demands for strictly convex cooperative games presented by Winter (1994). In this model, players in turn announce their demands publicly, indicating "I am willing to join any coalition yielding me a payoff of ..." and wait for these demands to be met by other players.

The bargaining starts with a randomly chosen player from N, say player i. This player announces their demand d_i publicly and then points to a second player who must give their demand. The game proceeds by having each player introduce a demand and then point at a new player to take a turn. If and when at some point a compatible demand is introduced, which means that a coalition S exists for which the total demand for players in S does not exceed $v(S)$, then the first player with such a demand selects a compatible coalition S. The players in S receive their demands and leave the game. The bargaining then continues with the rest of the players using the same rule on v restricted on $N \setminus S$. In a one-period implementation, players with unsatisfied demands at the end of the first period receive their individual value. However, in a T-period implementation with $T > 1$, T finite, if some players are left with unsatisfied demands after the first period, the bargaining procedure repeats for a second time with the set of these players by canceling their previous demands and charging them a fixed delay cost, and so on, until the T periods are over.

We present a formal description of the Winter mechanism with T periods ($T \geq 1$, T finite) as defined by Winter (1994). A decision point position m at period t is given by the vector $(S_1^{t,m}, S_2^{t,m}, d_{S_2^{t,m}}, j)$, where:

$0 \leq t \leq T$ is the current period of the bargaining,

$S_1^{t,m} \subseteq N$ is the set of players remaining in the game,

$S_2^{t,m} \subset S_1^{t,m}$ is the set of players who have submitted demands that are not yet met,

$d_{S_2^{t,m}} = (d_i)_{i \in S_2^{t,m}}$ is the vector of demands submitted by players in $S_2^{t,m}$, ($0 \leq d_i \leq \max_{S \subseteq N} v(S)$), and

$j \in S_1^{t,m} \setminus S_2^{t,m}$ is the player taking the decision by introducing a demand d_j. This player's demand d_j is said to be *compatible* if there exists some $S \subseteq S_2^{t,m}$ with $v(S \cup \{j\}) - \sum_{i \in S} d_i \geq d_j$. Otherwise, d_j is not compatible.

With j's decision, the game proceeds now in the following way:

1) If d_j is compatible, then j specifies a compatible coalition S, each player $i \in S \cup \{j\}$ is paid $d_i - tc$ (where c is the delay cost per period), and nature randomly chooses a player $k \neq j$ from $S_1^{t,m} \setminus S_2^{t,m}$. The new position is now given by $(t, S_1^{t,m+1}, S_2^{t,m+1}, d_{S_2^{t,m+1}}, k)$, with $S_1^{t,m+1} = S_1^{t,m} \setminus (S \cup \{j\})$ and $S_2^{t,m+1} = S_2^{t,m} \setminus (S \cup \{j\})$ (we remain at time t and we increment the position from m to $m+1$).

2) If d_j is noncompatible, then two cases are distinguished:

2_a) if $S_2^{t,m} = S_1^{t,m} \setminus \{j\}$ (j is the last player to give their demand in the current period), then a new player k is chosen randomly from $S_1^{t,m}$ and the new position is given by $(S_1^{t+1,1}, \emptyset, k)$ (we increment the period from t to $t+1$ and we recommence back at period $m = 1$);

2_b) if $S_2^{t,m} \subset S_1^{t,m} \setminus \{j\}$, then j specifies a new player $k \neq j$ in $S_1^{t,m} \setminus S_2^{t,m}$ and the new position is $(S_1^{t,m+1}, S_2^{t,m+1}, d_{S_2^{t,m+1}}, k)$, with $S_1^{t,m+1} = S_1^{t,m}$ and $S_2^{t,m+1} = S_2^{t,m} \cup \{j\}$ (we remain at time t and we increment the position from m to $m+1$).

The game starts with the randomly chosen player $j \in N$. Then, the initial position is set to be $(N, \emptyset, d_\emptyset, j)$. It terminates either when there are no more players in the game (see point 1 above), or when $t = T$ and $S_1^{t,m} \cup \{j\} = S_2^{t,m}$. In the second case, each $i \in S_1^{t,m} \cup \{j\}$ is paid $v(\{i\}) - Tc$.

3.2 Ex ante and ex post equilibria of the Winter mechanism

The main result of Winter (1994) is stated by the following theorem.

Theorem 1 (Winter (1994)). *Let v be a strictly convex game. The demand commitment game has a unique subgame perfect equilibrium, which assigns equal probabilities at indifferences. At this equilibrium, the grand coalition forms at the end of the first period. As c*[1] *approaches zero, the equilibrium payoffs approach the Shapley value of the game v.*

Theorem 1 states that for both the one-period and the T-period implementations, the Winter mechanism has a unique subgame perfect equilibrium in which the grand coalition forms in the first period and the *ex ante* expected equilibrium payoff coincides with the Shapley value. The proof of this result is based on a backward induction analysis. In particular, the expected subgame equilibrium payoff at each period is given by the average of the payoffs obtained as *ex post* equilibria over all the possible orders of the remaining players for the remainder of the game, where different orders are assumed to have equal probabilities $1/n!$[2]. Different orders are assumed to have equal probabilities as, by the definition of the mechanism, the first player at each period is drawn with equal probabilities. Then, each player chooses the next bidder by assigning equal probabilities to all potential successors because the player's equilibrium payoff depends only on the set of the successors and not their actual order.

Regarding the *ex post* equilibrium payoff, in the one-period implementation, given a specific ordering of the players, each player demands the marginal contribution to the

[1] In the formulation of this theorem, it is assumed for simplicity that the delay cost c is equal to the smallest money unit, but the result continues to hold when the delay cost is equal to some integer multiple of the smallest money unit. As stated by Winter (1994), the existence of a smallest money unit is both motivated by the necessity of reducing players' sets of actions to finite sets and of making the exact implementation of the theoretical model possible by experiments.

[2] n is then replaced by the number of players still bargaining at that period.

set of their successors[3]. In the two-period implementation, instead, at equilibrium the first player to make a demand asks their Shapley value plus the delay cost times the number of remaining players, whereas the other players ask their Shapley value minus one delay cost. That is, the first player in the first period leaves the other players the possibility of demanding their expected payoff (received in the second period) during the first period of the game.[4]

We observe that the different implementations of the Winter mechanism theoretically present a first-mover advantage. We stress that these theoretical results hold under some specific assumptions, in addition to the already mentioned strict convexity of the game. In particular, the delay cost must not be too large[5].

4 The experimental setting

4.1 The games

For our analysis, we considered the four four-player games shown in Table 2 together with corresponding Shapley values. The equal division payoff vector is equal to $ED(v_k) = (25, 25, 25, 25)$ when $k = 1, 2$, and $ED(v_k) = (50, 50, 50, 50)$ when $k = 3, 4$.

The games were chosen to be capable of testing the axioms that we presented in Section 2.2. In Table 3, we detail with which game we aim to test each axiom. Note

[3]As the mechanism is defined in a discrete version, the first player demands a smallest unit less in order to leave an extra smallest unit more for the last player and to break his/her indifference between accepting formation of the grand coalition and receiving their individual value. However, this extra money unit becomes negligible as it approaches zero.

[4]The *ex post* equilibrium of the T-period implementation with $T > 2$ resembles the case where $T = 2$.

[5]We refer to the original paper by Winter (1994) for the detailed description of the assumptions under which such results hold. As already mentioned, the delay cost must not be too large. Moreover, the results about the *ex ante* and the *ex post* equilibria hold for a discrete version of the mechanism, and when the smallest money unit approaches zero.

Table 2: The games and their Shapley values

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	$\phi_1(v)$	$\phi_2(v)$	$\phi_3(v)$	$\phi_4(v)$
$v_1(S)$	0	5	5	10	20	20	25	20	25	25	50	60	60	60	100	22.08	23.75	23.75	30,42
$v_2(S)$	0	20	20	30	20	20	30	45	55	60	45	55	60	100	100	0	28.33	30.83	40.83
$v_3(S)$	$= v_1(S) + v_2(S)$															22.08	52.08	54.58	71.25
$v_4(S)$	$= 2v_1(S)$															44.16	47.5	47.5	60.83

that games 1, 3, and 4 are strictly convex, and game 2 is at least convex. As a consequence, all four games are monotonic. Even if the Winter mechanism is well defined for any cooperative game, Theorem 1 is not generally true for convex games that are not strict, such as is the case for game 2. The decision to implement a game that is not strictly convex was driven by the wish to test the null player axiom. However, the presence of this null player raises some issues concerning the theoretical prediction of the equilibrium outcome on such a game. For instance, in 2p implementation with a null player, the delay cost is always too high whatever its size, and the null player who makes their demand not as the first mover would always prefer to ask zero and leave the game rather than paying the delay cost and incurring a negative payoff. For this reason, in the following, and when analyzing game 2, we will allow the configuration $\{1\}$ and $\{2, 3, 4\}$ to be equivalent to the grand coalition. With game 2 being at least convex, we have the opportunity to test the robustness of the Winter mechanism when relaxing the hypothesis of strict convexity, regardless of the theoretical prediction.

Table 3: The axioms and the four games

Axioms	**Games**
Efficiency	**all games**
Symmetry	**games 1 and 4** (symmetry of players 2 and 3)
Additivity	**games 1, 2, and 3** (game 3 is defined as the sum of games 1 and 2)
Homogeneity	**games 1 and 4** (game 4 is defined as twice game 1)
Null player	**game 2** (player 2 is a null player)
Strong monotonicity	**all games** (the marginal contributions of player 1 are always higher in game 1 than in game 2, and also higher in game 4 than in game 3)
Fairness	**games 1, 2, and 3** (game 3 is defined as the sum of games 1 and 2)

We implemented the Winter mechanism with one period (1p) and two periods and with low and high delay costs (2pL and 2pH, respectively). Low delay costs are equal to 0.5 for games 1 and 2, and to 1 for games 3 and 4. High delay costs are equal to 2.5 for games 1 and 2, and to 5 for games 3 and 4.

4.2 The procedure

The experiment was conducted at the Institute of Social and Economic Research (ISER), Osaka University, between January and August 2019.[6] A total of 264 students, who had never participated in similar experiments before, were recruited as experimental subjects. There were 96 subjects for 1p treatment, and 84 each for the 2pL and 2pH treatments[7]. The experiment was computerized with z-Tree (Fischbacher, 2007) and participants were recruited using ORSEE (Greiner, 2015).

To control for potential ordering effects, each participant played all four games twice in one of the following four orders : 1234, 2143, 3412, and 4321. Between each game play session (called a round), players were randomly rematched into groups of four players, and participants were randomly assigned a new role within the newly created group. 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 rewards based on the points they earned in these two selected rounds with an exchange rate of 20 JPY = 1 points in addition to a 1,500 and 1,900 JPY participation fee for the 1p and 2p implementations, respectively. The experiment lasted on average 100 minutes for the 1p implementation and 130 minutes for the2p implementations,

[6] All data are available on reasonable request.

[7] The difference in the number of participants between the two mechanisms is a result of variations in the show-up rate among experimental sessions. The data of the 1p treatment is the same as the one used in Chessa et al. (2022).

including the instruction ($\sim$ 15 min), comprehension quiz ($\sim$ 5 min), and payment[8]. The average payments were 2,650 JPY, 3,110 JPY, and 2,960 JPY for the 1p, 2pL, and 2pH implementations, respectively.

5 Results

5.1 Grand coalition formation and efficiency

First, we investigate whether the three implementations succeeded in making the players reach an agreement and form a grand coalition. In Figure 1, we present the results about the grand coalition formation for the 1p, 2pL, and 2pH implementations and for the four games[9].

As game 2 is not strictly convex with the presence of the null player 1, we allow the partition $\{\{1\}, \{2, 3, 4\}\}$ as a realization of the grand coalition, as this coalition structure does not affect the total value that must be shared between the players[10].

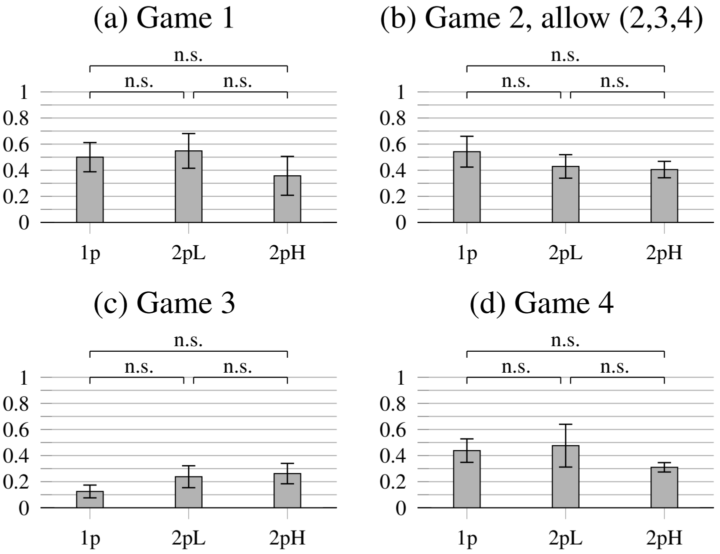
We may observe that, at best, the grand coalition formed slightly more (and often, much less) than 50% of the times for the four games, with no significant difference between the implementations. We may conclude that all three implementations of the Winter mechanism equally failed in enhancing complete cooperation. We observe that

[8]Participants received a copy of instruction slides, and prerecorded instruction movies were played. See Appendix A for the English translations of the instruction slides and the comprehension quiz.

[9]The figure is created based on the estimated coefficients of the following linear regressions: $gc_i = \beta_1 1p_i + \beta_2 2pL_i + \beta_3 2pH_i + \mu_i$, where gc_i is a dummy variable that takes the value of 1 if the grand coalition is formed, and 0 otherwise, in group i; $1p_i$, $2pL_i$, and $2pH$ are dummy variables that take a value of 1 if the 1p, 2pL, and 2pH implementations, respectively, are used, and 0 otherwise. 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 the two treatment dummies.

[10]Remember that the Winter mechanism is theoretically defined for strictly convex games. In this game, Player 1 always has a zero marginal contribution and, as such, can be left out of any coalition at no cost for them or the other players.

Figure 1: Proportion of times the grand coalition formed



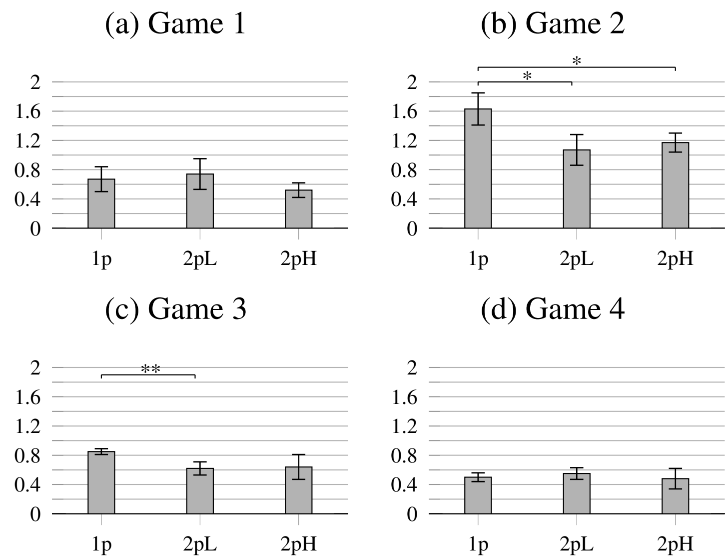
Note: The error bars show the one standard error range. The symbol *** indicates the proportion of times that the grand coalition formation was significantly different at the 1 % significance level (Wald test).

even when players were given a second chance in a 2p implementation, they did not manage to perform better in terms of grand coalition formation. In particular, Figure 2 illustrates the number of players whose demands were not met in the first loop. Surprisingly, their number is not higher (and, in some cases, is even significantly smaller) in the 2pL and 2pH implementations when compared with the 1p implementation. We may recall that the theoretical predictions expect the grand coalition to form in the first loop for the three implementations. However, one may expect players to demand more in the first loop of a 2p implementation because of the second chance of forming a coalition if their request is not met on the first try.

As a direct consequence of the failure to form the grand coalition, we report a failure in achieving full efficiency, with again no significant difference between the implementations, regardless of the presence of some delay costs in 2pL and 2pH (see Figure 3)[11].

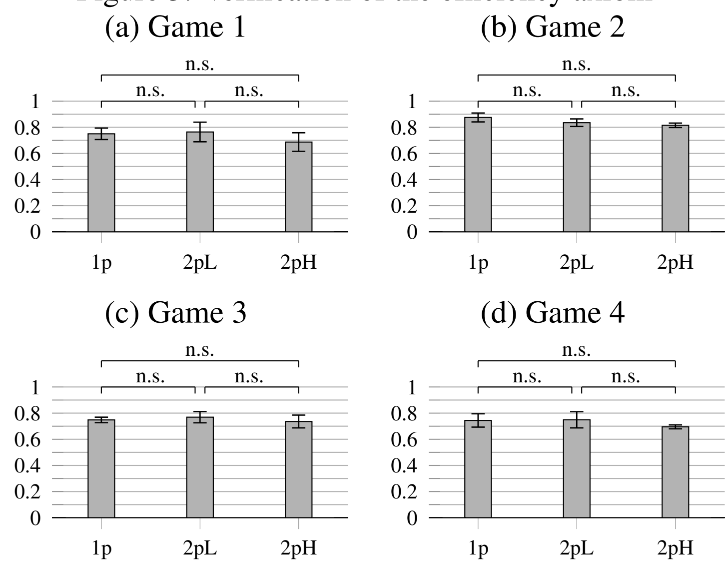
[11]The figure is created based on the estimated coefficients of the following linear regressions: $Eff_i =$

Figure 2: Average number of players whose demands were not met in the first loop



Note: The error bars show the one standard error range. The symbols ***, **, and * denote significance at the 1%, 5%, and 10% significance levels, respectively (Wald test).

Figure 3: Verification of the efficiency axiom



Note: Error bars show the one standard error range. The symbols *** and ** indicate the proportion of time that verification of the efficiency axiom was significantly different at the 1% and 5% significance levels, respectively (Wald test).

$\beta_1 1p_i + \beta_2 2pL_i + \beta_3 2pH_i + \mu_i$ where $Eff_i \equiv \frac{\sum_i \pi_i}{v(N)}$ is the efficiency measure for group i; and $1p_i$, $2pL$, and $2pH$ are dummy variables that take a value of 1 for the 1p, 2pL, and 2pH treatment, respectively, and 0 otherwise. 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 two treatment dummies.

Efficiency is computed as the fraction of the sum of the payoffs obtained by the four players compared with the worth of the grand coalition of the considered game (100 for games 1 and 2 and 200 for games 3 and 4).

Therefore, we conclude that:

Result 1. *The Winter mechanism in its 1p, 2pL, and 2pH implementations provides mediocre results in terms of both coalition formation and efficiency.*

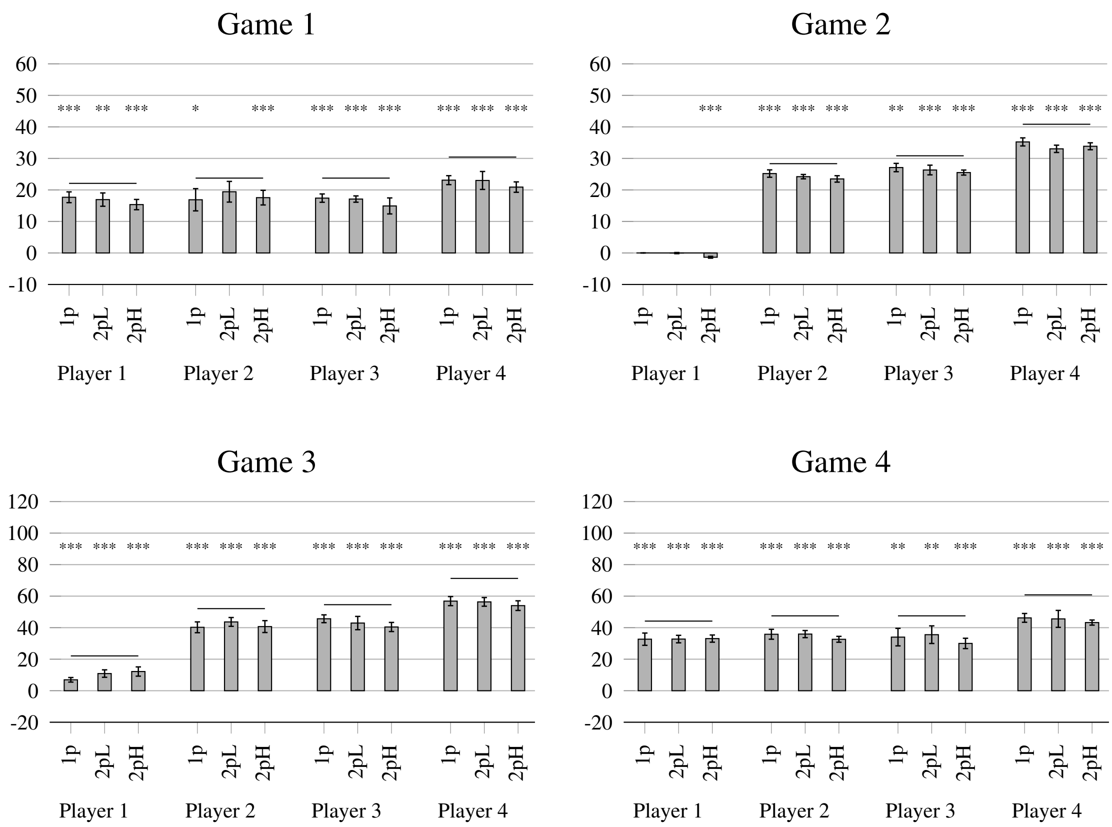
5.2 Payoff shares: *ex ante* theoretical prediction

According to the *ex ante* theoretical prediction, the Winter mechanism in all three implementations is expected to provide approximately the Shapley value on average over the different orders of the players. We let $\pi^{1p}(v_k)$ denote a vector of payoffs obtained by the players by implementing 1p in game k, with $k = 1, 2, 3, 4$. Analogously, we use $\pi^{2pL}(v_k)$ to denote a vector of payoffs obtained by the players by implementing 2pL, and $\pi^{2pH}(v_k)$ to denote a vector of payoffs obtained by the players by implementing 2pH. Figure 4 shows the mean of the payoffs in the four games and for the three implementations, with the horizontal lines indicating the Shapley value for each game[12].

As we may observe in Figure 4, as a consequence of the players often failing to form the grand coalition and the resulting lack of efficiency, the average realized payoff vectors are significantly different from the Shapley value. Therefore, we focus on investigating whether the proportion of the power share, *in lieu* of the absolute payoffs, converges to the Shapley value, by considering the normalized (to the worth of the grand coalition) payoff vectors. Then, in this and in the following sections, we consider the

[12]The error bars are based on the standard errors that are corrected for within-session clustering effects. These standard errors are obtained by running the system of linear regressions described in Section 5.4. The statistical tests are based on these regressions.

Figure 4: Mean of the payoffs for the three mechanisms, where the horizontal lines indicate the Shapley values



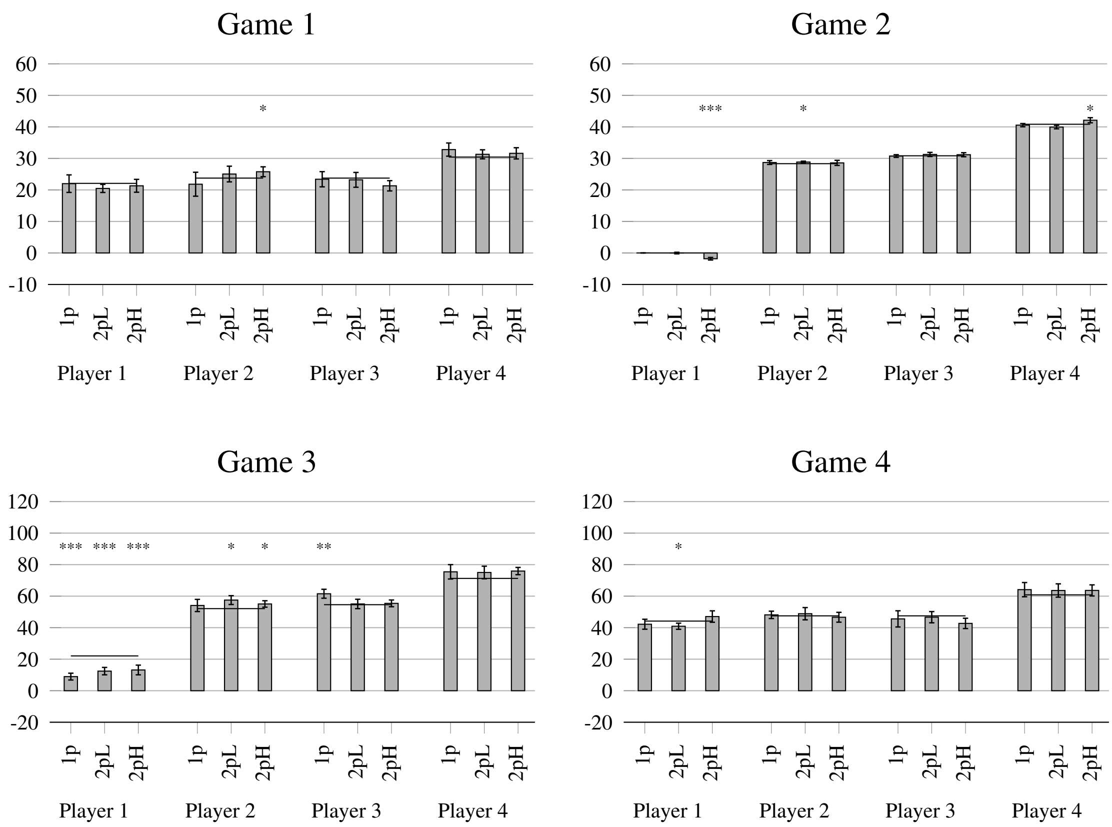
Note: The error bars show the one standard error range. The symbols ***, **, and * indicate the average normalized payoff being significantly different from the Shapley value at the 1%, 5%, and 10% significance levels, respectively (Wald test).

normalized vectors of payoffs with components $\widetilde{\pi}_i^m(v_k) = \frac{\pi_i^m(v_k)}{\sum_{j\in N}\pi_j^{1p}(v_k)} \times v_k(N)$ for each $i = 1, 2, 3, 4$ and for each $m \in \{1p, 2pL, 2pH\}$ (remember that the worth of the grand coalition is equal to 100 for games 1 and 2, and 200 for games 3 and 4).

Figure 5 shows the mean of the normalized payoffs in the four games, with the horizontal lines indicating the Shapley values for each game.

The three implementations perform well in implementing, on average, the Shapley value share. Moreover, we do not report any superiority of one of the three implemen-

Figure 5: Mean of the normalized payoffs for the three mechanisms, with the horizontal lines indicating the Shapley values

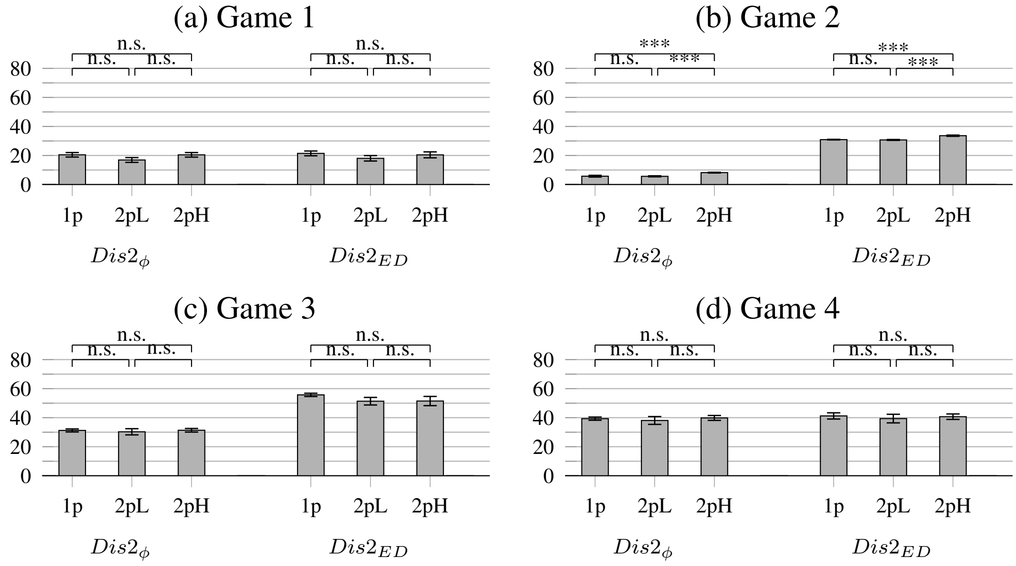


Note: The error bars show the one standard error range. The symbols ***, **, and * indicate the average normalized payoff being significantly different from the Shapley value at the 1%, 5%, and 10% significance levels, respectively (Wald test).

tations. Thus, we have the following result.

Result 2. *The Winter mechanism in its 1p, 2pL, and 2pH implementations provides good and comparable results in terms of implementation of the Shapley value power share.*

Figure 6: Mean of the distances of the normalized payoff vectors from the subgame perfect Nash equilibriums and the equal division solutions



Note: The error bars show the one standard error range. The symbols ***, **, and * indicate that the distance of the normalized payoff vectors from the Shapley value or from the equal division solution was significantly different at the 1%, 5%, and 10% significance levels, respectively (Wald test).

5.3 Payoff shares: *Ex post* theoretical prediction and first-mover advantage

The *ex post* theoretical prediction of the Winter mechanism is dependent on the ordering in which the players make their demands. In particular, a first-mover advantage is predicted. Furthermore, a higher first-mover advantage is expected in the 1p implementation, followed by the 2pH and then, finally, by the 2pL implementation. As a result, the distances between the Shapley value and the ex post theoretical predictions are largest in the 1p implementation, followed by the 2pH, and then the 2pL implementations.

Figure 6 shows the mean of the Euclidean distances of the normalized payoff vectors from the Shapley value, as well as from the equal division solution, for the four games. Such distances are computed as $Dis2^m_{\phi} = \sqrt{\sum_i(\widetilde{\pi}_i - \phi_i(v))^2}$ and $Dis2_{ED} =$

$\sqrt{\sum_i(\widetilde{\pi}_i - ED_i)^2}$, where $\phi_i(v)$ denotes the Shapley value for player i in game v[13].

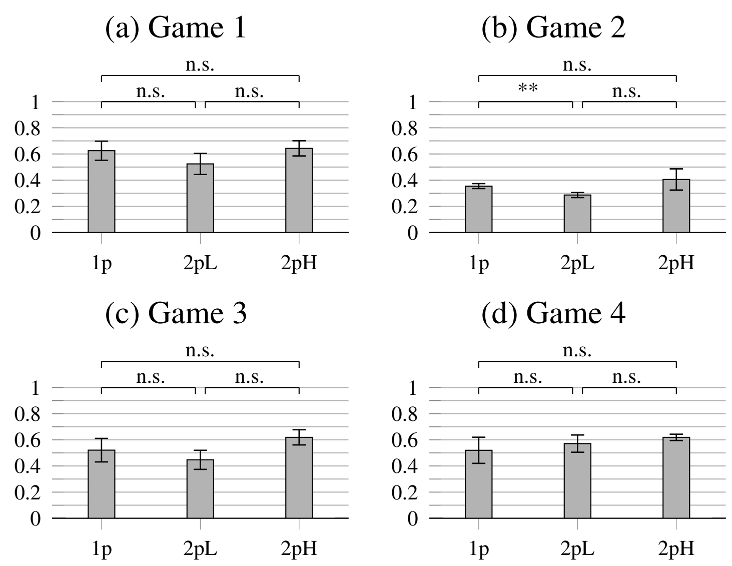
Contrary to the ex post theoretical predictions, we may observe that the distance of the realized normalized payoffs to the Shapley value in the three implementations are not significantly different in three out of four games. Only in Game 2 was $Dis2_\phi$ significantly larger in 2pH compared with 1p and 2pL. We also observe that the three implementations perform similarly in terms of distance to the equal division solution in three out of four games. The only exception is, again, Game 2, in which both 1p and 2pL are significantly closer to the equal division solution than 2pH. Therefore, we conclude that:

Result 3. *The Winter mechanism in its three implementations provides similar results in terms of the distance between the realized normalized payoffs and the Shapley value as well as the equal division solution.*

Figure 7 shows the proportion of times first-mover advantage appears, that is, when the first mover obtains a higher normalized payoff than their Shapley value. The three implementations perform in a similar way, and they do not show any first-mover advantage effect (notice that the first mover takes, on average, more than predicted by their Shapley value half of the time, and, consequently, less than predicted the other half of the times). Figure 8 details these results for each single player and Figure 9 presents the mean of the amount demanded as first mover. Again, we may observe that the three implementations perform in a similar way, regardless of the differences of the theoretical prediction. We can now state the following result.

[13]The figure is created based on the estimated coefficients of the following linear regressions: $Dis_i = \beta_1 1p_i + \beta_2 2pL_i + \beta_3 2pH_i + \mu_i$, where Dis_i is the relevant distance measure for groups i. $1p_i$, $2pL_i$, and $2pH$ are dummy variables that take a value of 1 if the 1p, 2pL, or 2pH treatments are used, respectively, and 0 otherwise. 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 the two treatment dummies.

Figure 7: Proportion of times first-mover advantage is verified according to the normalized payoff vectors



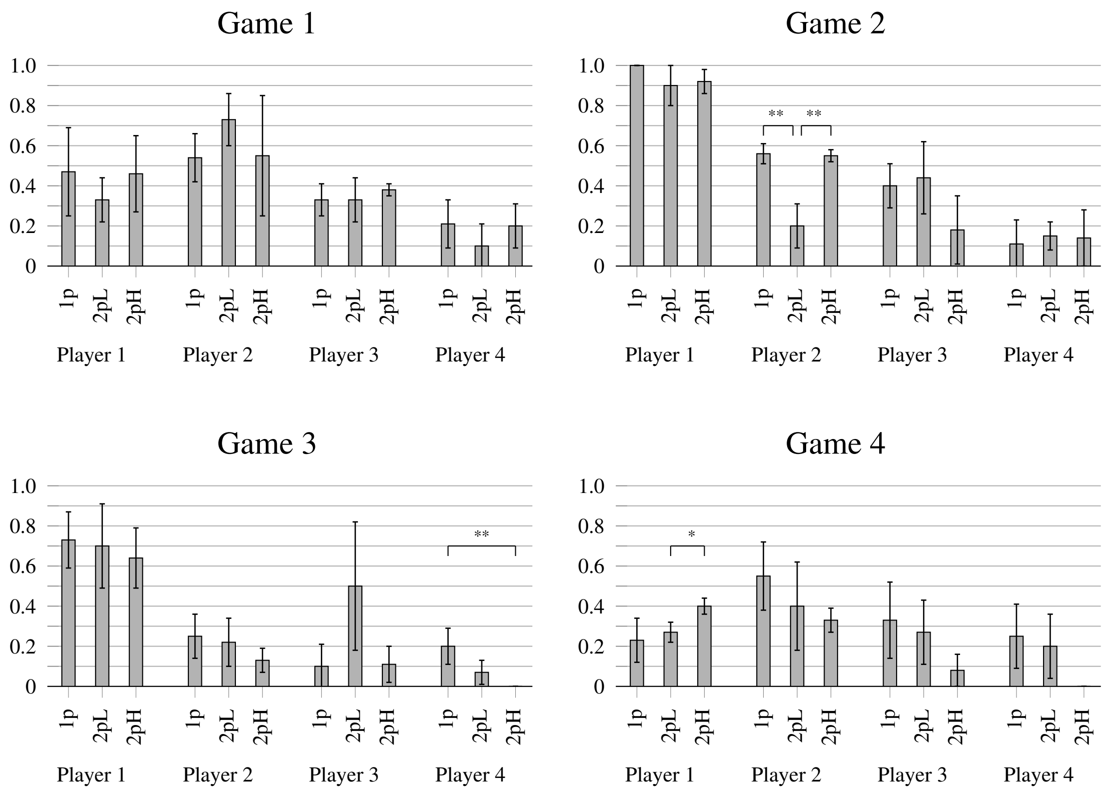
Note: The error bars show the one standard error range. The symbols ***, **, and * denote significance at the 1%, 5%, and 10% significance levels, respectively (Wald test).

Result 4. *The Winter mechanism in its 1p, 2pL, and 2pH implementations does not show any first-mover advantage effect.*

5.4 Testing for the axioms

To test for axioms (see Section 2.2), we propose two different approaches. The first approach investigates verification of the axioms based on the effective average normalized outcomes of each game. The second approach investigates whether different mechanisms perform differently in terms of decomposition of the Shapley distance *à la* Aguiar et al. (2021).

Figure 8: Frequency of the first mover demanding more than the Shapley value

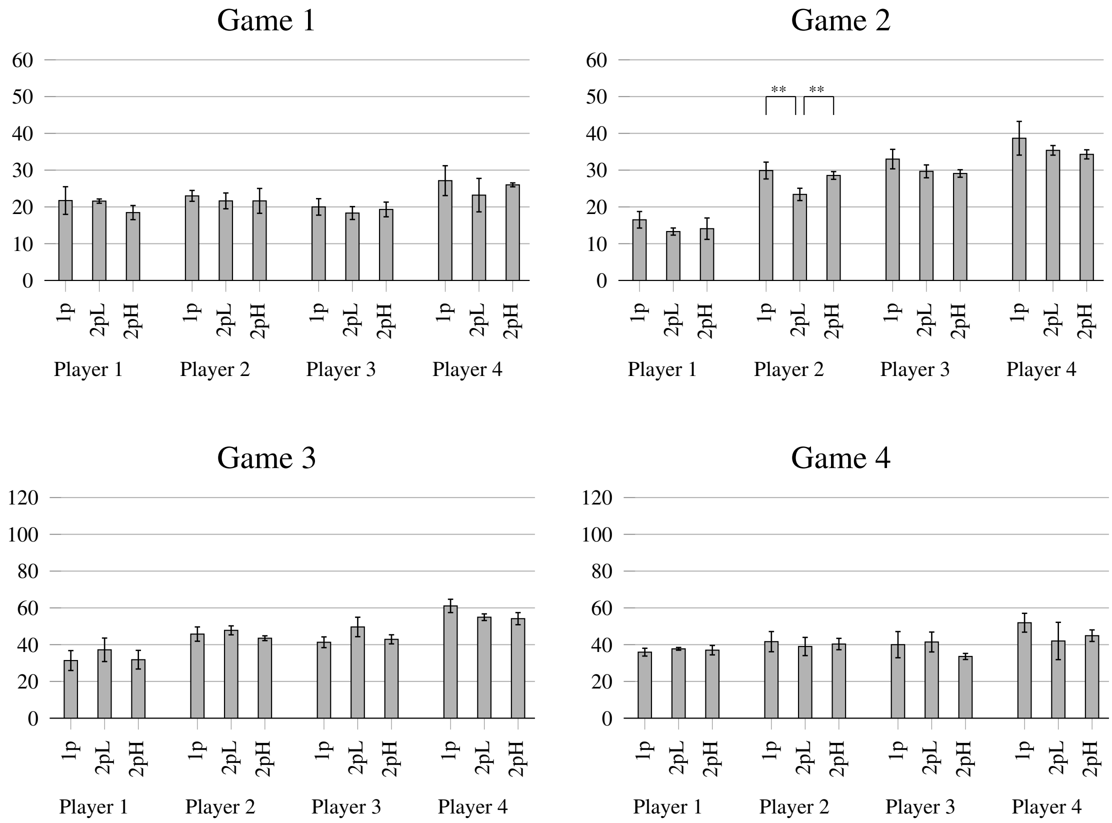


Note: The error bars show the one standard error range. The symbols ** and * indicate significant differences between treatments at the 5% and 10% significance levels, respectively (Wald test).

5.4.1 Verification of the axioms using the average normalized payoffs

To test symmetry, additivity, homogeneity, strong monotonicity, and fairness, we perform a set of ordinary least squares (OLS) regressions for the following system of equations, with the average normalized payoffs $\widetilde{\pi}_i$ as the dependent variables, g_1, g_2, g_3, and

Figure 9: Mean of the amount demanded as the first mover



Note: The error bars show the one standard error range. The symbol ** indicates significant differences between treatments at the 5% significance level (Wald test).

g_4 as the independent variables, and without a constant:

$$
\begin{aligned}
\widetilde{\pi}_1 &= a_1 g_1 + a_2 g_2 + a_3 g_3 + a_4 g_4 + u_1 \\
\widetilde{\pi}_2 &= b_1 g_1 + b_2 g_2 + b_3 g_3 + b_4 g_4 + u_2 \\
\widetilde{\pi}_3 &= c_1 g_1 + c_2 g_2 + c_3 g_3 + c_4 g_4 + u_3 \\
\widetilde{\pi}_4 &= d_1 g_1 + d_2 g_2 + d_3 g_3 + d_4 g_4 + u_4
\end{aligned}
\tag{1}
$$

where g_i is a dummy variable that takes a value of 1 if the game i is played, and 0 otherwise. Various axioms are tested based on the estimated coefficients of these regressions.

Symmetry requires that $b_1 = c_1$ and $b_4 = c_4$. Additivity and homogeneity require that $x_3 = x_1 + x_2$ and $x_4 = 2x_1$ for $x \in \{a, b, c, d\}$, respectively. The null player property requires that $a_2 = 0$, and strong monotonicity requires that $a_1 > a_2$ and $a_4 > a_3$. Finally, fairness requires that $b_3 - b_2 = c_3 - c_2$. In Table 6 in Appendix B, we present the results of Wald test of the verification of these axioms, together with the null hypothesis (H_0).

Symmetry (according to which H_0 should not be rejected) is fully confirmed by the 1p and the 2pL implementations. However, it is confirmed only for game 4 (half of the times) by the 2pH implementation. Additivity and homogeneity (according to which H_0 should not be rejected) are almost always confirmed by the three implementations. The null player property (according to which H_0 should not be rejected) is confirmed in 1p and 2pL but not in 2pH. In fact, there is no variation in the normalized payoff for player 1 in game 2 under 1p, and it is zero in all groups. The failure to satisfy the null player property under 2pH is mainly due to the large delay cost in 2pH. Strong monotonicity (according to which H_0 *should be rejected*) is confirmed by the three implementations. Fairness (according to which H_0 should not be rejected) is rejected by the 1p and the 2pH implementations but confirmed by the 2pL implementation. Table 4 summarizes whether each axiom is satisfied on average (+) or not (-) for the three implementations. To conclude this first approach for testing for axioms, we can state the following:

Result 5. *The Winter mechanism in the 1p, 2pL and 2pH implementations provides good and comparable results in terms of satisfaction of the axioms.*

Table 4: Winter mechanisms, axioms

Axiom	1p	2pL	2pH
Efficiency	–	–	–
Symmetry	+	+	–
Additivity	+	+	+
Homogeneity	+	+	+
Null player property	+	+	–
Strong monotonicity	+	+	+
Fairness	–	+	–

5.4.2 Shapley distance (Aguiar et al., 2021)

To strengthen our results on verification of the axioms, we implement the approach proposed by Aguiar et al. (2021) by computing the *Shapley distance*, which measures the distance of an arbitrary vector of payoffs to the Shapley value, and decomposes it into the failure of the symmetry, efficiency, and marginality axioms. In the following, we slightly adapt the original procedure by Aguiar et al. (2021) to test the axiomatization by Shapley (1953) based on efficiency, symmetry, additivity, and the null player because our games were selected to test these axioms. Here, we present a formal description of our procedure.

Given a (nonnormalized) vector of payoffs obtained by the players $\pi = (\pi_1, \pi_2, \pi_3, \pi_4)$:

Step 1. Find a vector of payoffs satisfying symmetry that is closest to π.

For symmetric players (players 2 and 3 in games 1 and 4, respectively), we must take the sum of their payoffs and this sum must be equally shared among them. For nonsymmetric players, we keep the same payoffs. At the end of this step, we obtain a new vector of payoffs denoted by $\pi^{sym} = (\pi_1^{sym}, \pi_2^{sym}, \pi_3^{sym}, and \pi_4^{sym})$.

Step 2. Find a vector of payoffs satisfying efficiency that is closest to π^{sym}.

For each player $i = 1, 2, 3, 4$, compute the new payoff $\pi^{sym,eff} = \pi^{sym} + [v(N) - \sum_{j \in N} \pi_j]/n$. At the end of this step, we obtain a new vector of payoffs denoted by $\pi^{sym,eff} = (\pi_1^{sym,eff}, \pi_2^{sym,eff}, \pi_3^{sym,eff}, and \pi_4^{sym,eff})$.

Step 3. Find a vector of payoffs satisfying the null player property that is closest to $\pi^{sym,eff}$.

If player i is a null player (player 2 in game 2), then their new payoff must be equal to zero, that is, $\pi_i^{sym,eff,null} = 0$. Otherwise, for the other players j, the payoffs of the null players in Step 2 must be equally shared among them, that is, $\pi_j^{sym,eff,null} = \pi_j^{sym,eff} + \sum_{i \in N^f} \pi_i^{sym,eff}/(n- \mid N^f \mid)$, where N^f is the set of null players. At the end of this step, we obtain a new vector of payoffs denoted by $\pi^{sym,eff,null} = (\pi_1^{sym,eff,null}, \pi_2^{sym,eff,null}, \pi_3^{sym,eff,null}, \pi_4^{sym,eff,null})$.

Step 4. Compute the Shapley distance and its components.

Following Theorem 3 in Aguiar et al. (2021), a vector of payoffs $\pi = (\pi_1, \pi_2, \pi_3, \pi_4)$ obtained when implementing game v can be decomposed as follows: $\pi = \phi(v) + e^{sym} + e^{eff} + e^{null} + e^{add}$ and $e^{\phi} = e^{sym} + e^{eff} + e^{null} + e^{add}$ is the Shapley "error" with:

$e_i^{sym} = \pi_i - \pi_i^{sym}$ for all i,

$e_i^{eff} = \pi_i^{sym} - \pi_i^{sym,eff}$ for all i,

$e_i^{null} = \pi_i^{sym,eff}$ if player i is a null player and $e_j^{null} = -\sum_{i \in N^f} \pi_i^{sym,eff}/(n- \mid N^f \mid)$ for the other players j,

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

Given this decomposition, the Shapley distance is given by:

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

where $< \cdot, \cdot >$ is the scalar product and for any vector $y \in \mathbb{R}^n$, $||y||^2 =< y, y >= \sum_{i \in N} y_i^2$[14].

To test for differences between the treatments, we run the following OLS regression by pooling the data from all four games:

$$||e^k||_g^2 = \beta_1 1p_g + \beta_2 2pL_g + \beta_3 2pH_g + U \tag{2}$$

The dependent variable is the components of the Shapley distance corresponding to the four axioms as well as the Shapley distance itself ($||e^k||_g^2$ with $k \in \{sym, eff, null, add, \phi\}$) for group g and the independent variables are $1p_g$, $2pL_g$, and $2pH_g$, which take a value of 1 if the corresponding treatment is used, and 0 otherwise. The standard errors are corrected for within-session clustering effects. The results are reported in Table 5.

It can be observed from Table 5 that in all three treatments, the main reasons for the deviation from the Shapley value are failures of efficiency and additivity. $||e^{eff}||^2$ accounts for 59.5%, 62.9%, and 65.1% of the Shapley distance ($||e^{\phi}||^2$) in 1p, 2pL, and 2pH, respectively, and the corresponding values for $||e^{add}||^2$ are 31.5%, 28.8%, and 27.8%, respectively. The null player property is largely respected and thus $||e^{null}||^2$ is an order of magnitude smaller compared with the other components, accounting for,

[14]Unlike the original decomposition by Aguiar et al. (2021), which ensures orthogonal components, in our decomposition, in general, vectors e^{null} and e^{add} are not orthogonal, so that $< e^{add}, e^{null} >$ is not equal to zero. However, in our data, $2 < e^{add}, e^{null} >$ are very small (on average, they are -0.08, -0.08, and -0.09 in 1p, 2pL, and 2pH, respectively, based on the estimation results reported below) compared with other components.

	$\|\|e^{sym}\|\|^2$	$\|\|e^{eff}\|\|^2$	$\|\|e^{null}\|\|^2$	$\|\|e^{add}\|\|^2$	$\|\|e^{\phi}\|\|^2$
1p	85.18	606.81	7.28	321.49	1020.68
	(18.54)	(99.06)	(1.83)	(16.94)	(70.60)
2pL	71.48	613.24	9.89	280.67	975.2
	(11.29)	(84.04)	(2.58)	(8.13)	(82.14)
2pH	72.15	730.06	8.26	311.69	1122.07
	(9.18)	(72.82)	(0.71)	(25.88)	(45.34)
No. Obs	528	528	528	528	528
R^2	0.148	0.292	0.102	0.407	0.462
p-value*	0.802	0.491	0.719	0.108	0.252

Standard errors are in parentheses.
* p-values for testing $H_0 : 1p = 2pL = 2pH$ (based on the Wald test)

Table 5: Result of Shapley distance decomposition. Based on pooling the data of all groups and all games

at most, 1% of the Shapley distance. We also observe that there are no statistically significant differences in terms of the size of each of the components across the three treatments.

6 Conclusions

In this paper, we provide an experimental comparison of three different implementations of the Winter demand commitment bargaining mechanism: that is, 1p, 2pL, and 2pH implementations. These three implementations predict the same *ex ante* outcomes but differ in terms of *ex post* outcomes. However, our experiment shows that the three different implementations provide comparable results for both ex ante and ex post outcomes. No significant difference appeared in any of our investigation domains: that is, coalition formation, alignment with the theoretical prediction, and satisfaction of axioms.

An example that we borrow from Winter (1994) on bargaining over the formation of a government may help in presenting the implications of our results. Bargaining over government formation is a process that naturally resembles the demand commitment model with more than one period. Parliamentary negotiations are usually based on demands rather than proposals. These demands are often not compatible in the first period, and at least a second round of requests is implemented to find an agreement. A second round may be costly in terms of time and it can make the bargaining process unnecessarily slow and cumbersome. However, lengthening the bargaining process is often considered essential and crucial for parties to match and for a coalition to form.

Surprisingly, our experimental results suggest that this may not always be the case, that is, that extending the bargaining process is not always necessary and crucial for a coalition. In fact, our three implementations resulted in similar outcomes in all our investigation domains. The key message of our paper is that a mechanism designer should implement the lightest possible mechanism for bargaining whenever possible because refinements may turn out to be not only costly to implement, but ineffective in terms of quality of the performances. In fact, players converge to similar outcomes (e.g., total or partial cooperation) without taking advantage of any second chances, and regardless of the different theoretical predictions, as the differences are not matched behaviorally.

Acknowledgment

The experiments reported in this paper were approved by the Independent Review Board of Yamaguchi University (No. 5). We gratefully acknowledge financial support from the Joint Usage/Research Center at ISER, Osaka University, and Grants-in-aid for Scientific Research from the Japan Society for the Promotion of Science (15K01180, 15H05728, 18K19954, and 20H05631), the Fund for the Promotion of Joint International Research

(Fostering Joint International Research) (15KK0123), and the French government-managed l'Agence Nationale de la Recherche under Investissements d'Avenir UCA^{JEDI} (ANR-15-IDEX-01). In particular, we thank the UCAinACTION project.

References

AGUIAR, V.H., R. PONGOU AND J.-B. TONDJI (2018): "A nonparametric approach to testing the axioms of the Shapley value with limited data," *Games and Economic Behavior*, 111, 41–63.

CHESSA, M., N. HANAKI, A. LARDON, AND T. YAMADA (2022): "An experiment on the Nash program: Comparing two strategic mechanisms implementing the Shapley value," ISER DP No. 1176, Osaka University.

DE CLIPPEL, G. AND K. ROZEN (forthcoming): "Fairness through the lens of cooperative game theory: An experimental approach," *American Economic Journal: Microeconomics*

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

FRÉCHETTE, G., J. KAGEL, AND M. MORELLI (2005): "Behavioral identification in coalition bargaining: An experimental analysis of demand bargaining and alternating offers," *Econometrica*, 73, 1893–1937.

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

GUL, F. (1989): "Bargaining foundations of Shapley value," *Econometrica*, 57, 81–95.

HARSANYI, J. (1981): "The Shapley value and the risk dominance solutions of two bargaining models for characteristic-function games," in *Essays in Game Theory and Mathematical Economics in honor of Oskar Morgenstern*, ed. by R. J. Aumann et al., Mannheim: Bibliographisches Institut Mannheim, 43–68.

HART, O. AND J. MOORE (1990): "Property rights and the nature of the firm," *Journal of Political Economy*, 98, 1119–1157.

HART, S. AND A. MAS-COLELL (1996): "Bargaining and value," *Econometrica*, 64, 357–380.

KRISHNA, V. AND R. SERRANO (1995): "Perfect equilibria of a model of n-person noncooperative bargaining," *International Journal of Game Theory*, 24, 259–272.

LI, S. (2017): "Obviously strategy-proof mechanisms," *American Economic Review*, 107, 3257–3287.

LUCCHETTI, R., S. MORETTI, F. PATRONE, AND P. RADRIZZANI (2010): "The Shapley and Banzhaf values in microarray games," *Computers & Operations Research*, 37, 1406–1412.

NASH, J. (1950): "The bargaining problem," *Econometrica*, 18, 155–162.

——— (1953): "Two-person cooperative games," *Econometrica*, 21, 128–140.

PEREZ-CASTRILLO, D. AND D. WETTSTEIN (2001): "Bidding for the surplus: A noncooperative approach to the Shapley value," *Journal of Economic Theory*, 100, 274–294.

SERRANO, R. (2005): "Fifty years of the Nash program, 1953–2003," *Investigaciones Economicas*, 29, 219–258.

——— (2008): “Nash program,” in *The New Palgrave Dictionary of Economics, 2nd edition*, ed. by S. Durlauf and L. Blume, McMillan, London.

——— (2014): “The Nash program: A broader interpretation,” *Ensayos*, 33, 105–106.

——— (2021): “Sixty-seven years of the Nash program: Time for retirement?” *SERIEs*, 12, 35–48

SHAPLEY, L. (1953): “A value for n-person games,” in *Contribution to the Theory of Games* vol. II, 303–317, ed. by H. Kuhn and A. Tucker, Princeton University Press, Princeton, NY

VAN DEN BRINK, R. (2002): “An axiomatization of the Shapley value using a fairness property,” *International Journal of Game Theory*, 30, 309–319.

WINTER, E. (1994): “The demand commitment bargaining and snowballing cooperation,” *Economic Theory*, 4, 255–273.

YOUNG, H. P. (1985): “Monotonic solutions of cooperative games,” *International Journal of Game Theory*, 14, 65–72.

A Translated instructions and comprehension quiz

An English translation of the instruction materials as well as the quiz (shown on the screen) can be downloaded from

- `https://www.dropbox.com/s/galeo3todbah7iw/Winter_1_loop_handout.pdf?dl=0` for the Winter one-period implementation,
- `https://www.dropbox.com/s/kig2i59ncbw9vjw/Winter_2_loop_handout.pdf?dl=0` for the Winter two-period implementation.

B Verification of axioms

Table 6: Winter mechanisms' Wald tests for the verification of the symmetry, additivity, homogeneity, null player, strong monotonicity, and fairness axioms

		1p		2pL		2pH	
Axiom	H_0	χ^2	p-value	χ^2	p-value	χ^2	p-value
Symmetry	$b_1 = c_1$	0.08	0.781	0.15	0.694	12.91	0.0003
	$b_4 = c_4$	0.14	0.712	0.11	0.742	0.30	0.581
Additivity	$a_3 = a_1 + a_2$	7.25	0.007	5.51	0.019	1.77	0.184
	$b_3 = b_1 + b_2$	0.65	0.422	1.70	0.193	0.05	0.815
	$c_3 = c_1 + c_2$	2.54	0.111	0.03	0.862	1.37	0.243
	$d_3 = d_1 + d_2$	0.35	0.555	0.50	0.479	0.31	0.579
Homogeneity	$a_4 = 2a_1$	0.06	0.805	0.00	0.979	1.61	0.204
	$b_4 = 2b_1$	0.37	0.542	0.10	0.756	29.04	0.000
	$c_4 = 2c_1$	0.02	0.892	0.02	0.892	0.00	0.991
	$d_4 = 2d_1$	0.35	0.552	0.03	0.870	0.01	0.922
Null player	$a_2 = 0$	.	.	0.01	0.905	20.27	0.000
Strong monotonicity	$a_1 = a_2$	62.74	0.000	221.37	0.007	196.89	0.000
	$a_4 = a_3$	147.12	0.000	44.21	0.000	25.57	0.000
Fairness	$b_3 - b_2 = c_3 - c_2$	7.53	0.006	1.52	0.217	4.09	0.043