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Bargaining with confirmed proposals: an experimental analysis of tacit cooperation on duopoly games

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Abstract

We investigate the performance of a bargaining over strategies protocol with confirmed proposals applied to duopoly markets modeled after Bertrand *vs.* Cournot competition, while neutralizing the price- *vs.* quantity-setting framing. The bargaining protocol was implemented with either *symmetric* (i.e., alternating between the two players) or *asymmetric* (i.e., assigned solely to one player) confirmation power for agreeing on the strategies to be played in the duopoly market. We characterize the set of subgame perfect equilibrium outcomes of the bargaining game with confirmed proposals for each of the four combinations of market game and confirmation power. Based on these characterizations, we formulate experimental hypotheses, disentangling the four features of collusive agreements: equity, welfare-maximization, Pareto-efficiency, equilibrium outcomes. Our experimental results broadly validate previous findings of more cooperative behavior in Bertrand than in Cournot duopolies. Alternating confirmation power only increases the speed of cooperation. The key factor in the bargaining protocol is the confirmation option, rather than the equal assignment of this option.

JEL codes: C72, C78, C91.

Keywords: Bargaining, Tacit collusion, Experiments, Duopoly, Confirmed proposals.

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1 Introduction

Bargaining over strategies to be played in a non-cooperative game represents a form of communication between players, which is often sufficient to achieve a cooperative outcome. Moreover, the bargaining over strategies protocol aligns with common practices when two or more parties establish a commitment rule that fully describes the actions to be followed by both. In this paper, we examine a specific protocol for bargaining over strategies, focusing on two-player bargaining games referred to as *games with confirmed proposals*.

Different from standard bargaining over strategies, which may allow verbal communication, and in which there is a large set of potential messages and interchange protocols whose efficiency cannot be clearly assessed or controlled, bargaining over strategies in the form of confirmed proposals represents a simple language communication, whose only messages are the possible strategies of the original game. This form of standardized communication can be effective in situations where engaging in open discussion is challenging. In such situations, signaling the strategies parties intend to pursue may be a more subtle and discreet way of communicating. This scenario may be representative of conflict resolution, where open dialogue is often difficult, or of covert contracting, as seen in cartel formation among competing firms. In the specific context of this paper, the primary emphasis and motivation revolve around the concept of cooperation in duopoly games.

Games with confirmed proposals are interactive strategic situations in which at least one player, in order to officially accept a contract, must confirm his/her proposal in combination with the proposal of his/her opponent. The most well-known two-player bargaining game with a confirmed proposal is the famous *bargaining over a pie* model by Rubinstein [1982]. In this model, players may reach an agreement on how to share a fixed-size pie through an alternating proposal protocol.

The seminal paper by Rubinstein has inspired several experiments on two-person sequential bargaining in games presented in extensive form. The underlying question is always whether or to what extent subgame perfect equilibrium accounts for actual behavior when facing the problem of dividing a given surplus (the pie). We may cite here the comprehensive research work by Rapoport, who addressed the issue experimentally under different conditions: when information is incomplete and we may observe different levels of discount factor [Rapoport et al., 1995], under equal and unequal bargaining cost [Rapoport et al., 1990], in the presence of equal and unequal discount factor [Weg et al., 1990], and when the opt out option is enforced or optional [Weg et al., 1996].

Such classical problem, as many bargaining games and experiments that appeared in the following years, typically takes the size of the pie as given and abstract from problems that might arise when the pie has to be generated through cooperation in the first place. However, in many real-life situations, players often have to resolve cooperation and bargaining problems in one go, that is the size of the pie and the sharing rule have to be decided simultaneously [Fischer and Normann, 2019]. In this spirit, Attanasi et al. [2015] propose an infinite time-horizon bargaining over strategies game with confirmed proposals and apply it to several common two-player games: the Prisoner's Dilemma, the Hawk-Dove Game, the Trust Game, and the Ultimatum Game. In each of these games, they prove theoretically that equilibrium agreements of the bargaining process are Pareto-efficient and typically different from the Nash equilibrium of the original game. Attanasi et al. [2013] apply such protocol in a laboratory experiment on an infinite time-horizon game built over the Prisoner's Dilemma, showing that the equitable and Pareto-efficient agreement is reached by almost all bargaining pairs and that assigning the power of confirmation of the proposal to only one of the two players, rather than alternating this role, significantly increases the probability of signing a cooperative agreement in the very first bargaining period. Then, even when experiments on bargaining games have repeatedly shown that subjects usually fail to use backward induction [Suleiman, 2018], bargaining-over-strategies with confirmed proposals has instead proved to provide more satisfying results in the lab.

Motivated by these positive results, in our paper, we investigate a bargaining over strategies process with confirmed proposals, along the lines of Attanasi et al. [2013, 2015]. In our games, two players sign a contract about how they will play in one of two (discretized) duopoly markets. These markets may be interpreted as discretized versions of two duopoly markets, namely one with price-setters *à la* Bertrand and another one with quantity-setters *à la* Cournot. We may observe that in such games, bargaining with confirmed proposals does not serve simply in agreeing on how to share a surplus *à la* Rubinstein, but it acts more as a coordination game on some favorable outcomes.

The experimental literature reports that collusive (cooperative) behaviors are frequently observed in markets with two firms, under both price and quantity competition, even if more collusive behavior is detected in price-setting experiments when compared to quantity-setting experiments [Suetens and Potters, 2007]. The level of collusion dramatically increases when experimental subjects can communicate among themselves. Fonseca and Normann [2012] compare pricing behavior with and without the possibility of communication (through a non-face-to-face talking) between firms in Bertrand oligopolies with various numbers of firms. They find strong evidence that communication helps firms coordinate in collusive pricing schemes. Waichman et al. [2014], instead, investigate the impact of two different kinds of communication on quantity-setting behavior in a Cournot market: "standardized" vs. "free" communication, showing how the second performs better in a student population. An alternative stream of experimental research shows that collusive behavior may occur even if the conversation can merely be imagined through a "virtual bargaining", in which players need to imagine a bargaining process without actually communicating [Melkonyan et al., 2017].

Game-theoretic literature supports the intuition that the higher propensity for collusive behavior in Bertrand rather than Cournot duopoly might not stem from the difference in game framing – i.e., price-setting vs. quantity-setting – but rather from the differing payoff matrices induced by the two models [Vives, 1999]. Specifically, given the same market price (i.e., the size of the pie to be shared), the two duopolies can be disentangled according to the market surplus' sharing rule. Bertrand duopoly with homogeneous products features a *Winner-Take-All* game, where the low-price setter captures the entire market demand and the high-price one earns nothing [Baye and Morgan, 2002, Hoernig, 2007, Frank and Cook, 2013]. Players' payoff functions in this model are discontinuous, with an extreme discontinuity along the price diagonal [Amir and Evstigneev, 2018]. In contrast, in a Cournot duopoly with homogeneous products, players' payoff functions are continuous, with less extreme payoff differences for differing strategies. This is due to the division of market demand based on production levels, ensuring that even the low-quantity setter earns a positive payoff. In this sense, the Cournot duopoly can be interpreted as a *Sharing* game: the firms' (quantities) strategies determine their respective share of the market, i.e., the sharing of the market surplus (profits) among the two firms. Although the term is not commonly used in the literature to describe Cournot duopoly models, it aligns with the nature of Cournot competition, particularly in contrast to the Bertrand duopoly: firms' strategies inherently involve the sharing of market surplus, with payoff distributions that are less extreme than in *Winner-Take-All* games [Beckman, 2003].

With this setup, we conduct our experiments without referencing a market demand or distinguishing between price-setting and quantity-setting. We propose a 4x4 simultaneous game, where the payoff matrix is constructed by substituting a vector of four prices or four quantities into the market demand function, depending on the treatment (*Winner-Take-All* or *Sharing*, respectively). The two vectors are pre-determined to ensure that the four egalitarian outcomes along the matrix's main diagonal are identical across treatments. Among these outcomes, the collusive agreement is the only Pareto-efficient one, while the Cournot equilibrium ranks second, and the Bertrand equilibrium ranks last in terms of Pareto efficiency. Ensuring the same egalitarian outcomes in both treatments allows us to isolate and observe the higher propensity for collusive behavior in the Bertrand duopoly compared to the Cournot duopoly, driven solely by differences in off-diagonal agreements.

This also motivates our use of a bargaining over strategies process as a form of standardized communication between players in these discretized duopoly games. Instead of directly playing the 4x4 one-shot non-cooperative game, the two players engage in a bargaining process over their strategies. A confirmed agreement specifies a pair of independent strategies derived from the original one-shot non-cooperative game. The game concludes when one of the players confirms the agreement reached through a proposal-counterproposal sequence. The absence of strictly positive payoff profiles in all off-diagonal cells of the winner-take-all (Bertrand) matrix is expected to intensify competition, reducing trial-and-error behavior compared to the sharing (Cournot) matrix. In the latter, the presence of positive payoffs in all off-diagonal cells softens competition. This dynamic is expected to encourage players to reach equitable agreements more quickly and with greater frequency in the winner-take-all treatment.

As in Attanasi et al. [2013], we implement the bargaining protocol with both *symmetric* (alternating proposals) and *asymmetric* confirmation power (unilateral proposals). In the latter protocol, unlike the classical Rubinstein [1982] game, the player proposing first remains the same throughout and is the only one who can confirm the agreement. This constitutes our second treatment manipulation. We consider this relevant not only because leader-follower competition is characteristic of oligopoly markets in general and of oligopoly experiments in particular [Huck et al., 2001, Güth et al., 2006]. Alternating confirmation power is expected to be more effective in facilitating tacit coordination, as it reduces the opportunity for the proposer to confirm (excessively) inequitable agreements. With this, assigning confirmation power exclusively to one player is anticipated to decrease both the frequency of collusive agreements and the speed of their confirmation.

The resulting four bargaining games potentially involve an infinite number of stages and strategies. Nonetheless, under mild assumptions on players' impatience in the potentially infinite sequence of bargaining periods, we characterize the set of subgame perfect equilibrium outcomes for the bargaining game with confirmed proposals, considering each of the four combinations of payoff matrix (winner-take-all vs. sharing) crossed with confirmation power (symmetric vs. asymmetric). Based on these characterizations, we formulate hypotheses to explore the implications of these differing setups.

We focus on the analysis of duopolies, as they are of particular interest in the economic literature. Duopolies represent some of the earliest and most relevant applications of interactive strategic reasoning, making them a natural choice for testing a relatively new approach aimed at studying the consequences on cooperation of bargaining with confirmed proposals. In particular, they serve as formal models of social dilemma-like situations. In this regard, they share with the Prisoner's Dilemma the tension between cooperation and defection, as well as the resulting sub-optimality of the Nash equilibrium. Previous experimental results on bargaining with confirmed proposals on strategies of the Prisoner's Dilemma show astonishing cooperation rates, around 90% [Attanasi et al., 2013]. We posit that this may be because repeated 2x2 social dilemmas are relatively simple to understand, enabling players to quickly grasp how to achieve cooperation through learning by doing.[1] Conversely, models of market competition confront decision-makers with more complex strategic choices. Our discretized versions, cleansed of the price-setting and quantity-setting framing, provide a tool for direct comparison with previous studies on the Prisoner's Dilemma.

More precisely, we exploit the more complex 4x4 payoff matrices to disentangle the factors that play a predominant role in the negotiation process toward an agreement. For both types of duopolies – winner-take-all and sharing matrices – and for both proposal protocols – symmetric and asymmetric – we conduct an analysis of the possible agreements on the final outcome dis-

[1] Literature on the repeated Prisoner's Dilemma is vast. See, between the many, the classical paper by Kreps et al. [1982].

tribution. Specifically, we examine whether such agreements are: equitable,[2] welfare-maximizing, (strongly) Pareto-efficient, and subgame perfect equilibria of the bargaining game with confirmed proposals. From a theoretical perspective, we demonstrate that the sets of equilibria in the games with confirmed proposals differ significantly between winner-take-all and sharing matrices. The latter exhibits a larger set of possible equilibria, potentially leading to a more complex negotiation process. We analyze the agreements that exhibit one or more of these properties under both symmetric and asymmetric confirmation power, and assess how these factors might influence the likelihood of reaching an agreement more quickly.

We test our theoretical predictions through two experimental studies involving more than 200 participants each (422 in total). Both studies implement the same four treatments – defined by the intersection of the two game matrices and the two proposal protocols – on a between-subject basis. The two studies differ only in how we operationalized the mild assumptions required to account for the potentially infinite number of bargaining periods and players' impatience.

Our results only partially confirm those of Attanasi et al. [2013] on the Prisoner's Dilemma, as the detected cooperation rate is significantly lower than 90%. This aligns with our intuition that coordination is more challenging in social dilemma games with more than two strategies per player. Nevertheless, the finding that more than half of the pairs (on average across the four treatments and the two studies) confirm the only agreement that is equitable, welfare-maximizing, (strongly) Pareto-efficient, and an equilibrium provides further evidence that bargaining with confirmed proposals serves as an effective communication mechanism in competitive environments.

More importantly, in each of the two studies, we observe better performance in the winner-take-all (Bertrand) treatments compared to the sharing (Cournot) treatments, regardless of the confirmation power. This validates previous extensive evidence of more collusive behavior in Bertrand than in Cournot duopoly, even in our case, where the price-setting vs. quantity-setting framing distinction is absent. Finally, alternating confirmation power has essentially no effect on the frequency of collusive agreements although it increases the speed at which they are confirmed. This further supports the conclusion of Attanasi et al. [2013] that the key factor for cooperation in the bargaining protocol is the confirmation option, while the "equal" assignment of this option merely facilitates earlier cooperation.

The remainder of the paper is organized as follows. Section 2 provides the definitions and theoretical analysis of the four games with confirmed proposals. Section 3 outlines the experimental design and procedures, as well as the theory-driven experimental hypotheses. The experimental results are presented in Section 4. Finally, Section 5 offers the concluding remarks.

[2]Equity, as in the *bargaining over a pie* model by Rubinstein [1982], is often cited as a critical factor, playing a crucial role in the acceptance of a proposal, even in competitive settings [Kreps et al., 1982, Bolton and Ockenfels, 2000, Georgantzís and Attanasi, 2016].

2 Bargaining games with confirmed proposals

Let S_i be the finite strategy space for player i in the original game. Starting from the original game, we define an infinite time-horizon Game with Confirmed Proposals (henceforth, GCP). The GCP has a potentially infinite sequence of bargaining *periods* t, with $t = 1, 2, ..., \infty$. In each period, one player acts as a proposer, and the other player acts as a respondent. Each period t has three *stages*, denoted as $(t.I)$, $(t.II)$, and $(t.III)$. In each stage, only one player is active: the proposer is active at $(t.I)$ and $(t.III)$, and the respondent is active at $(t.II)$. In the first two stages, $(t.I)$ and $(t.II)$, the two players sequentially declare the strategy they intend to play (proposal stages); $(t.III)$ is the confirmation stage, in which the active player decides whether to confirm (*Yes*) or not (*No*) the strategy profile resulting from the proposals of the first two stages. Hence, the game can end only if the proposer accepts the strategy profile, which then becomes a confirmed agreement between the two players. Formally, if S_i represents the set of possible strategies (proposals) for player $i = 1, 2$, then the 3-stage path (s_1, s_2, Yes) in period t confirms the agreement (s_1, s_2), whereas (s_1, s_2, No) moves the game to period $t + 1$.

The proposer in each period t can be randomly chosen or picked up according to any predetermined rule. In the paper, we consider two confirmed proposal settings, in which the proposer in each period is picked according to the following rules: the symmetric GCP, where there is alternating power of confirmation, and the asymmetric GCP, in which the proposer is the same in every period of the game.

Symmetric GCP. In the symmetric version of the game, the player that is randomly selected to be the proposer (respondent) at the beginning of the game will play as proposer (respondent) in period 1, and in each odd period; the opponent will play as proposer (respondent) in each even period. Hence, players alternate in exerting power to end the game by confirming the agreement reached in a period.

Asymmetric GCP. In the asymmetric version of the game, the player that is randomly selected to be the proposer (respondent) at the beginning of the game will play as the proposer (respondent) in period 1 and each subsequent period. Hence, only this player has the power to end the game by confirming the agreement reached in a period.

Assumptions on players' preferences. Following Attanasi et al. [2013], we make three assumptions on players' preferences: (i) *Disagreement is not better than any (confirmed) agreement:* If an agreement is never reached, the outcome is the disagreement event in which each player has a payoff lower than or equal to the minimum payoff of the game. (ii) *Impatience:* The time of agreement is relevant, and between two identical agreements, a player will always prefer the one arriving at an earlier period. (iii) *Stationarity:* The preference between two agreements within the same bargaining period does not depend on the period.

2.1 The Winner-Take-All game

The first GCP we consider is one where the original game is derived by a (discretized) price-setting duopoly. The two players may be thought as firms that produce homogeneous products and compete by setting prices, in a Bertrand-like market characterized by the linear demand $Q = 12 - 2P$. We assume that both firms have marginal (and fixed) costs equal to zero. For each player i, the set of possible price strategies is $S_i = \{1, 2, 3, 4\}$. This game, neutralized of the price-setting framing, is described by the matrix in Table 1.

Table 1: Matrix of Take-All game

	1	2	3	4
1	5,5	10,0	10,0	10,0
2	0,10	8,8	16,0	16,0
3	0,10	0,16	9,9	18,0
4	0,10	0,16	0,18	8,8

As in the experimental implementation and in the following discussion, we do not focus on the duopoly market interpretation, but on the matrix structure of the corresponding discretized game, to the classic term "collude," we prefer the more neutral term "cooperate." Note that if the two firms cooperated, their cooperation outcome (corresponding to the collusive outcome of the corresponding duopoly model) would be obtained by setting $p = 3$, which corresponds in duopoly theory to the monopoly price, thus leading each firm to a profit of 9. In this discretized version, the Nash equilibrium of the original game is found at the lowest possible price greater than the (null) marginal cost, i.e., $p_1 = p_2 = 1$, thus leading to a profit of 5.

From now on, we refer to the strategic game with matrix given by Table 1 as to the *Winner-Take-All* game. We refer with the same name to the corresponding bargaining GCP, specifying when the power of confirmation is symmetric or asymmetric. Propositions 1 and 2 characterize the equilibrium outcomes of the symmetric and asymmetric case, respectively. Note that being the proposer in the asymmetric case (weakly) increases the payoff with respect to the symmetric case, while being the respondent (weakly) decreases it. This is due to the fact when player i is the proposer he/she can ensure for him/herself a payoff of at least 5 by choosing $p_i = 1$. In a symmetric game, therefore, player i will never obtain anything lower than 5 in equilibrium. However, if player i is the respondent in the asymmetric case, the minimum payoff he/she can obtain for certain is 0. This difference weakly increases payoffs for the proposer and weakly decreases payoffs for the respondent in the asymmetric case.

Proposition 1. *The Winner-Take-All GCP with symmetric power of confirmation has a unique subgame perfect equilibrium outcome, the cooperative agreement* $(3, 3)$*. This equilibrium outcome can be confirmed in any bargaining period* $t = 1, 2, ..., \infty$*.*

Proof. Consider the game in Table 1. First of all, notice that players cannot agree in equilibrium on any contract off the diagonal, in which one of the two players receives zero payoff. In any period t, if the proposer receives zero payoff, he/she will not have an incentive to confirm the contract, as he/she can always commit to playing the strategy $(1, Yes)$, i.e., proposing $p = 1$ in stage $(t.I)$ and confirming in stage $(t.III)$ regardless of the price proposed by the respondent in stage $(t.II)$. This strategy would allow him/her a payoff of at least 5 in period t. If it is the respondent who receives zero payoff from the contract, he/she will not have an incentive to propose the specified strategy, as he/she can always commit to playing the strategy $(1, Yes)$ in period $t + 1$, where he/she would become the proposer. This strategy would allow him/her a payoff of at least 5 in period $t + 1$.

Also, $(1, 1)$ cannot be an equilibrium agreement. This can be verified by using a stationarity argument. Given that the game horizon is infinite, all subgames starting in odd nodes are identical, and the same holds for all subgames starting in even nodes. Since the players are rational, strategy profiles confirmed in period t will be the same as the ones that would have been confirmed at $t + 2$, with $t = 1, 2, ..., \infty$. We, therefore, characterize a subgame perfect equilibrium based solely on stationary strategies. Let us assume that $(1, 1, Yes)$ is an equilibrium outcome. In a stationary equilibrium, the payoff profile at the end of period $t = 1$ has to coincide with the payoff profile at the end of period $t > 1$, for each $t = 1, 2, ..., \infty$. Moreover, the game starting in period t and the one in period $t + 1$ are isomorphic for each t, as the set of strategies in the two games are the same and the original game in Table 1 is symmetric. Therefore, we can assign to each non-terminal node at the end of every bargaining period t the payoff profile $(5, 5)$ of our suggested equilibrium. This implies that the payoff profile in the continuation game at the end of period 1 is $(5, 5)$ for all non-terminal histories. That would lead the first proposer, say player 1, to choose Yes at the end of period 1 in every node after a proposal-counterproposal path leading to a payoff profile on or above the diagonal of the matrix in Table 1. Moreover, the payoff he/she obtains in the terminal node $(1, 1, Yes)$ is the same as in the non-terminal node $(1, 1, No)$, due to stationarity. Hence, he/she is indifferent between confirming the contract $(1, 1)$ and not confirming it. Going backward, in any case, the respondent (player 2) would best reply to a price p with the same price, as replying to p with a lower price would lead to the contract being rejected, which gives a strictly lower payoff for any $p > 1$. Hence, at the beginning of period 1, player 1 would propose the cooperative price 3, player 2 would respond with the same price 3, and player 1 would confirm, thus leading to the payoff profile $(9, 9)$ at the end of period 1, which contradicts that the confirmed agreement $(1, 1, Yes)$ is a stationary equilibrium outcome. In the same way, we can rule out $(2, 2)$ and $(4, 4)$ as equilibrium agreements.

Therefore, only $(3, 3)$ can be an equilibrium agreement. Let us verify that the GCP may end in some period t with the following outcome: $(3, 3, Yes)$. Assume that period t is a period in which player 1 is the proposer. Given that we assign to each non-terminal node at the end of bargaining period t the payoff profile $(9, 9)$, the proposer confirms the contracts where $p_1 < p_2$ and does not decline $(3,3)$, given that he/she gets the same payoff in the terminal node $(3,3,Yes)$ and in the non-terminal node $(3,3,No)$ and, when indifferent, he/she will confirm because of the preference for an early agreement.[3] Going backward, the respondent would best reply to any p_1 with $p_2 = p_1$, so that the proposer is indifferent between proposing any price at the beginning of the period, as prices different from 3 will lead to a rejected contract and to the same continuation payoff as $(3,3,Yes)$. Therefore, the agreement $(3,3)$ can be confirmed in equilibrium in each bargaining period t. ■

Proposition 2. *The Winner-Take-All GCP with asymmetric power of confirmation has two subgame perfect equilibrium outcomes, the cooperative agreement* $(3,3)$*, and the agreement* $(3,4)$*. These equilibrium outcomes can be confirmed in any bargaining period* $t = 1, 2, ..., \infty$*.*

Proof. Consider the game in Table 1. Assume that player 1 is randomly selected to be the proposer in each bargaining period. With this asymmetric power of confirmation, players cannot agree in equilibrium on any contract with $p_1 > p_2$, as each of these contracts gives the proposer a payoff of 0. This can be proved by using the same argument of Proposition 1.

Let us now consider contracts where $p_1 < p_2$, which give player 2 (the respondent) a payoff of 0. Among these contracts, only $(3,4)$ can be an equilibrium agreement. This is because player 2 cannot commit to any counterproposal that can yield him/her a higher payoff with certainty. For example, let us show by contradiction that $(1,2)$ cannot be an equilibrium agreement. If $(1,2)$ is an equilibrium agreement, by stationarity each non-terminal node at the end of every bargaining period is associated with the payoff profile $(10,0)$. Given that the proposer gets the same payoff in the terminal node $(1,2,Yes)$ and in the non-terminal node $(1,2,No)$, he/she is indifferent between confirming or not $(1,2)$, and, when indifferent, he/she will confirm because of the preference for an early agreement. On the other hand, he/she will not confirm any contract which leads to a payoff lower than 10. Going backward, the respondent (player 2 in all periods) is indifferent between any price in all nodes in which he/she is active (he/she would get a payoff of 0 whatever his/her counterproposal), but, due to the preference for early agreement, he/she will propose a price greater than 1, in order to have the agreement. Moreover, if the proposer offers 2, the respondent will optimally choose 3 or 4, and if the proposer offers 3, the respondent will optimally choose 4. As a consequence, the proposer strictly prefers to offer 3, instead of 1, and therefore $(1,2)$ cannot be an equilibrium outcome. The same argument can be applied to show that $(1,3)$, $(1,4)$, $(2,3)$ and $(2,4)$ cannot be equilibrium agreements.

Conversely, we can show with a stationarity argument that $(3,4)$ is an equilibrium agreement. If $(3,4)$ is the equilibrium agrement, by stationarity each non-terminal node at the end of every bargaining period t is associated to the payoff profile $(18,0)$. Given that the proposer (player 1 in all periods) gets the same payoff in the terminal node $(3,4,Yes)$ and in the non-terminal node

[3] Our impatience assumption is very mild and it applies only as a tie-breaking rule. Given that we are considering a discretized duopoly, and hence the set of possible actions is finite, this is equivalent to model discounting with δ almost equal to 1.

$(3, 4, No)$, he/she is indifferent between confirming or not $(3, 4)$, and, when indifferent, he/she will confirm because of the preference for an early agreement. On the other hand, he/she will not confirm any contract which gives him/her a payoff lower than 18. Going backward, the respondent (player 2 in all periods) is indifferent between any price in all nodes in which he/she is active (he/she would get a payoff of 0 whatever his/her counterproposal), but, due to the preference for early agreement he/she will propose a price equal to 4, in order to have the agreement. With this, we can conclude that $(3, 4)$ is an equilibrium outcome.

Let us now consider the agreements on the diagonal of Table 1, where $p_1 = p_2$. Note that $(1, 1)$ cannot be an equilibrium agreement. To see this, if $(1, 1, Yes)$ is an equilibrium outcome − and so we can assign the payoff profile $(5, 5)$ to each non-terminal node at the end of the bargaining period t −, the proposer confirms any other contract on the diagonal and above the diagonal (they all give player 1 a payoff greater than 5), while contracts below the diagonal are declined. Moving backward, the respondent finds it optimal to propose $p_2 = p_1$ for any strategy p_1 of the proposer. Hence, the proposer finds it optimal to choose $p_1 = 3$, which leads to a higher payoff. In the same way, we can show that $(2, 2)$ and $(4, 4)$ are not sustainable as confirmed contracts in equilibrium. The fact that the agreement $(3, 3)$ can be confirmed in equilibrium in any bargaining period t can be easily proved by assigning the payoff profile $(9, 9)$ to each non-terminal node at the end of bargaining period t, and following the stationarity argument used in the proof of Proposition 1. ■

2.2 The Sharing game

The second GCP we consider is one where the original game is derived by a (discretized) quantity-setting duopoly. The two players may be thought as firms that produce homogeneous products and compete by setting quantities, in a Cournot-like market characterized by the inverse linear demand $P = 6 - \frac{Q}{2}$. We assume that both firms have marginal (and fixed) costs equal to zero. Note that the setting (demand and firms' cost functions) is the same as the price-setting duopoly of the first GCP. For each player i, the set of possible quantity strategies is $S_i = \{2, 3, 4, 5\}$. The original game is therefore described by the matrix in Table 2.

Table 2: Matrix of Sharing game

	5	4	3	2
5	5,5	7.5,6	10,6	12.5,5
4	6,7.5	8,8	10,7.5	12,6
3	6,10	7.5,10	9,9	10.5,7
2	5,12.5	6,12	7,10.5	8,8

As for the previous game, to the classic term of duopoly theory "collude," we prefer the more neutral term "cooperate." Note that if the two firms cooperated, their cooperation outcome (corresponding to the collusive outcome of the corresponding duopoly model) would be obtained by setting $q_1 = q_2 = 3$, which corresponds in duopoly theory to the monopoly quantity of 6 (sold at the monopoly price $p = 3$) and leading each firm to a profit of 9 (same as in the Winner-Take-All game of Table 1). The Nash equilibrium of the original game, found at the intersection of the two best-reply functions, is $q_1 = q_2 = 4$, thus leading to a profit of 8. Observe that this Nash equilibrium does not coincide with the Nash equilibrium of the Winner-Take-All game: $p_1 = p_2 = 1$ in Table 1 corresponds to $q_1 = q_2 = 5$ in Table 2, leading to a profit of 5.

From now on, we refer to the strategic game with matrix given by Table 2 as to the *Sharing game*. We refer in the same way to the corresponding bargaining GCP, specifying when the power of confirmation is symmetric or asymmetric. Propositions 3 and 4 characterize the equilibrium outcomes of the symmetric and asymmetric case, respectively. As in the Winner-Take-All game, being a proposer in the asymmetric game weakly increases payoffs, while being a respondent weakly decreases them.

Proposition 3. *In the Sharing GCP with symmetric power of confirmation, the set of subgame perfect equilibrium outcomes is* $\{(3,3),(4,3),(4,2),(3,2),(3,4),(2,3),(2,4)\}$. *These equilibrium outcomes can be confirmed in any bargaining period* $t = 1, 2, ..., \infty$.

Proof. Consider the game in Table 2. First of all, notice that players cannot agree in equilibrium on contracts $(5,5)$, $(2,5)$, and $(5,2)$, in which one of the two players receives a payoff of 5 (lowest possible payoff). In any period t, if the proposer receives payoff 5 he/she will not have an incentive to confirm the contract, as he/she can always commit to playing the strategy $(4, Yes)$, allowing him/her a payoff of at least 6 in period t. If it is the respondent who receives a payoff of 5 from the contract, he/she will not have an incentive to propose the specified strategy, as he/she can always commit to playing the strategy $(4, Yes)$ in $t+1$, allowing him/her a payoff of at least 6 in period $t+1$.

Also, $(4,4)$ cannot be an equilibrium agreement. This can be verified by using a stationarity argument along the lines of the proof of Proposition 1. Recall that we can assign to each non-terminal node at the end of every bargaining period t the payoff profile $(8,8)$ of our suggested equilibrium. This implies that the payoff profile in the continuation game at the end of period 1 is $(8,8)$ for all non-terminal histories. That would lead the first proposer, player 1, to choose Yes at the end of period 1 in the following proposal-counterproposal nodes $\{(5,3),(5,2),(4,3),(4,2),(3,2)\}$. Moreover, the payoff he/she obtains in the terminal node $(4,4,Yes)$ is the same as in the non-terminal node $(4,4,No)$, due to stationarity. Hence, he/she is indifferent between confirming the contract $(4,4)$ and not confirming it. He/she is also indifferent between confirming contract $(2,2)$ and not confirming it, as it gives him/her the same payoff as the continuation payoff. Going backward, in any case, the respondent (player 2) would best reply to a quantity $q_1 < 5$ with the same quantity, as replying to q_1 with a higher quantity would lead to the contract being rejected by player 1, which gives player 2 a lower payoff. Hence, at the beginning of period 1, player 1 would propose the cooperative quantity 3, player 2 would respond with 3, and player 1 would confirm, thus leading to the payoff profile $(9, 9)$ at the end of period 1, which contradicts that the confirmed agreement $(4, 4, Yes)$ is a stationary equilibrium outcome. In the same way, we can rule out $(2, 2)$, $(4, 5)$ and $(5, 4)$ as equilibrium agreements.

Furthermore, $(5, 3)$ cannot be an equilibrium agreement. As a matter of fact, in such an equilibrium, in periods in which player 1 is the proposer, he/she confirms any contract in which his/her payoff is at least 10, including contract $(4, 3)$, which delivers a higher payoff for player 2. As a consequence, whenever it is his/her turn to propose, player 2 proposes $q_2 = 3$ and confirms only counterproposals with $q_1 < 5$. With the same argument, it is possible to show that $(3, 5)$ is not an equilibrium agreement.

On the contrary, $(3, 3)$ is an equilibrium agreement. Let us verify that the game may end in some period t with the following outcome: $(3, 3, Yes)$. Assume that period t is a period in which player 1 is the proposer. Given that we assign to each non-terminal node at the end of the bargaining period t the payoff profile $(9, 9)$, the proposer confirms the contracts where $q_1 > q_2$ and does not decline $(3, 3)$, given that he/she gets the same payoff in the terminal node $(3, 3, Yes)$ and in the non-terminal node $(3, 3, No)$. Going backward, the respondent would best reply to any $q_1 < 5$ with $q_2 = q_1$, and we have already excluded all equilibria where player 1 proposes $q_1 = 5$. Hence, in such an equilibrium, at the beginning of period t, player 1 proposes $q_1 = 3$, player 2 responds with $q_2 = 3$, and player 1 confirms. The case in which in period t the proposer is player 2 is symmetric. Therefore, the agreement $(3, 3)$ can be confirmed in equilibrium in each bargaining period t.

In the same way, we can show that $(4, 3)$, $(4, 2)$, $(3, 2)$, $(3, 4)$, $(2, 3)$ and $(2, 4)$ are equilibrium outcomes. For example, consider $(4, 3)$, and verify that the game may end in some period t with the following outcome: $(4, 3, Yes)$. Assume that period t is a period in which player 1 is the proposer. Given that we assign to each non-terminal node at the end of the bargaining period t the payoff profile $(10, 7.5)$, the proposer confirms the contracts $(5, 2)$ and $(4, 2)$, and does not decline the contracts $(5, 3)$, $(4, 3)$, $(3, 2)$ given that he/she gets the same payoff in the terminal node $(5, 3, Yes)$, $(4, 3, Yes)$ and in the non-terminal node $(5, 3, No)$ and $(4, 3, No)$. Recall that we already ruled out $(5, 2)$ and $(5, 3)$ as possible confirmed agreements, therefore, the only agreements that can be confirmed are $(4, 3)$, $(4, 2)$ and $(3, 2)$. Going backward, the respondent would best reply to $q_1 = 4$ with $q_2 = 3$, and to $q_1 = 3$ with $q_2 = 4$. Hence, in such an equilibrium, at the beginning of period t, player 1 proposes $q_1 = 4$, player 2 responds with $q_2 = 3$, and player 1 confirms. If in period t the proposer is player 2 he/she will confirm all agreements with $q_1 < 5$, $q_2 < 5$ with the exclusion of $(4, 2)$, and $(3, 2)$. Going backward, player 1 would best reply to $q_2 = 4$ with $q_1 = 5$, to induce player 2 not to confirm the agreement, because he/she gets a higher payoff in the non-terminal node $(4, 3, No)$ than in the terminal nodes $(q_1, 4, Yes)$ with $q_1 < 5$. Similarly, he/she will respond to $q_2 = 2$ with $q_1 > 2$, and the corresponding agreement is not confirmed by player 2, because player 1 gets a higher payoff in the non-terminal node $(4, 3, No)$ than in the terminal nodes $(2, 2, Yes)$, which is the only one that can be confirmed when player 2 proposes q_2. Finally, player 1 best responds to $q_2 = 3$ with $q_1 = 4$. Player 2, therefore, proposes $q_2 = 3$ because it induces the terminal node $(4, 3, Yes)$, while any other proposal induces a non-terminal node in which he/she has the same payoff, but with a later agreement. Therefore, the agreement $(4, 3)$ can be confirmed in equilibrium in each bargaining period t. ■

Proposition 4. *In the Sharing GCP with asymmetric power of confirmation, the set of subgame perfect equilibrium outcomes is* $\{(5, 3), (5, 2), (4, 3), (4, 2), (3, 3), (3, 2)\}$. *These equilibrium outcomes can be confirmed in any bargaining period* $t = 1, 2, ..., \infty$.

Proof. Consider the game in Table 2. If there is asymmetric power of confirmation, players cannot agree in equilibrium on any contract with $q_1 < q_2$, as each of these contracts gives the proposer a payoff lower than the cooperative one, $(3, 3)$.

Let us now consider contracts where $q_1 > q_2$. Among these contracts, only $(5, 4)$ cannot be an equilibrium agreement. This is because both players have a payoff that is lower than the cooperative one. With the same argument, we can rule out $(5, 5)$, $(4, 4)$ and $(2, 2)$ as possible equilibrium agreements.

Conversely, the fact that the agreement $(3, 3)$ can be confirmed in equilibrium in any bargaining period t can be easily proved by assigning the payoff profile $(9, 9)$ to each non-terminal node at the end of bargaining period t, and following the stationarity argument used in the proof of Proposition 3. Similarly, we can show that $(5, 3)$, $(5, 2)$, $(4, 3)$, $(4, 2)$, and $(3, 2)$ can be sustained as equilibrium agreements. ■

2.3 Structure of the payoff matrices and equilibria distribution

In the experimental implementation of both the *Winner-Take-All* and *Sharing* games (the original games with matrices as in Tables 1 and 2, respectively), we denote the strategies set of a player as $\{A, B, C, D\}$. For example, strategy A for player 1 corresponds to choosing the first row, denoted as (a price of) 1 in the former original game and (a quantity of) 5 in the latter one. Note that the payoff matrices of the two original games are built so that the cooperative outcome is obtained with the agreement on the strategy profile (C, C), and that the equitable agreements on the diagonal correspond to the same price-quantity allocation for each firm in the duopoly interpretation that originated our models. The two original games differ in what happens off the diagonal. These distinctions are intrinsic to the strategic differences between the price-setting duopoly (used to construct the *Winner-Take-All* game) and the quantity-setting duopoly (used to construct the *Sharing* game). As mentioned in the Introduction, the matrix structures were deliberately designed to neutralize the price- vs. quantity-setting framing, allowing the analysis to focus on the primary feature under investigation in this paper: the winner-take-all payoff distribution of a price-setting duopoly vs. the less extreme payoff differences characteristic of a quantity-setting duopoly.

The theory-driven experimental hypotheses in the next section are based on a comparison of the features of the different outcomes from the two matrices presented in Tables 1 and 2. These features are categorized according to four main criteria. The first three criteria depend solely on the outcome structure of the original games and do not require solving the infinite time-horizon GCP. Therefore, it is possible to determine which outcomes satisfy these three criteria irrespective of the confirmation power in the GCP, whether symmetric or asymmetric. Specifically, for each possible outcome of the two 4x4 matrices, we identify whether the outcome is equitable[4], welfare-maximizing[5], or Pareto-efficient[6]. Figure 1 provides a visual representation of the set of outcomes that satisfy each of these properties within the payoff matrix of the two original games.

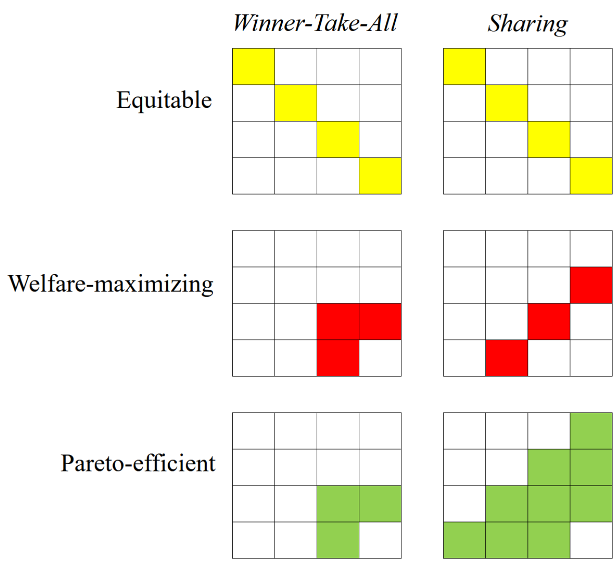

Figure 1: Equitable, welfare-maximizing and (strongly) Pareto-efficient agreements in the *Winner-Take-All* and in the *Sharing* game matrices of payoffs (resp., Tables 1 and 2)

The fourth criterion follows from our equilibrium analysis (see Propositions 1-4), i.e., we consider whether an outcome can be obtained as an equilibrium agreement of the GCP. Figure 2 shows the set of outcomes that can be agreements in subgame perfect equilibria of the GCP. As the set of subgame perfect equilibria of the GCP depends both on the payoff matrix of the original game

[4]An outcome is "equitable" if it ensures equal payoff for both subjects.

[5]An outcome is "welfare-maximizing" if it maximizes the total payoff across all subjects.

[6]An outcome is "Pareto-efficient" if there is no alternative outcome that makes at least one party better off without making any other party worse off.

and on the type of confirmation power (symmetric vs. asymmetric), we have four different sets of equilibrium agreements.

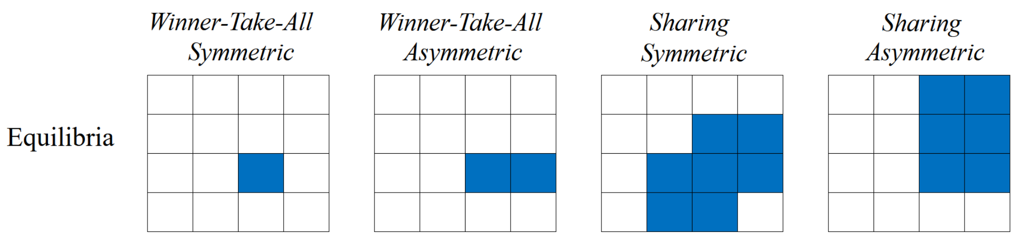

Figure 2: Subgame perfect equilibrium agreements in *GCP* with *Winner-Take-All* vs. *Sharing* payoff matrix crossed with *Symmetric* vs. *Asymmetric* power of confirmation (of player 1)

Note that the cooperative agreement (C, C) (line 3, column 3 of Figures 1-2) in all *Winner-Take-All* and *Sharing* GCP, both with symmetric or with asymmetric power of confirmation, is uniquely defined as the only agreement satisfying both the equitable and the welfare-maximizing property (or, equivalently, as the only agreement satisfying both the equitable and the Pareto-efficiency property). In addition, (C, C) is also a subgame perfect equilibrium of all the four GCP. As a result, it is the only agreement satisfying all aforementioned properties in Figure 1 and in Figure 2 for each game.

3 The experiment

3.1 Procedures and design

The experiment was run at the LEEN, Laboratory of Experimental Economics of Nice. It was computerized with z-Tree [Fischbacher, 2007], and participants were recruited using ORSEE [Greiner, 2015]. The experiment is divided into two parts: Study 1 and Study 2.[7] Below, we provide detailed information specific to each study, along with the common elements shared between the two.[8]

Study 1

Study 1 was run in May 2022. We held 17 sessions with a total of 208 participants. Each person could only participate in one of these sessions. Average earnings were €13.40, including a €5 show-up fee (minimum and maximum earnings were respectively €5 and €23); the average duration of a session was 35 minutes, including instructions, questionnaire, and payments.

[7] We preregistered Study 2 hypotheses and analysis plan on the Aspredicted (193911) at `https://aspredicted.org/9v9q-wbyv.pdf`.

[8] Experimental instructions are available in Online Appendix at this link: CLICK HERE.

At the start of the experimental session, as in Attanasi et al. [2013], participants were informed that:

(a) *[Termination rule in case of disagreement] In the absence of a confirmed agreement during any period, the game would conclude after 90 minutes.*

To prevent the formation of uncontrolled beliefs regarding the implications of this time limit on the number of periods played, we limited the duration of each negotiation period to a maximum of 3 minutes (80 seconds for each participant's proposal and counterproposal, and 20 seconds for the confirmation stage). This approach guaranteed that at least 30 periods could be played, even if each period took the maximum allowable time.

(b) *[How to leave the lab in case of agreement] If a pair reached an agreement, the participants in that pair would not have to wait for other pairs to leave the laboratory.*

Once a pair confirmed an agreement, a message on the screen instructed them to wait calmly until the experimenters escorted them out of their cubicles, ensuring that they did not encounter one another to maintain anonymity. They were then directed to separate rooms, where they were individually paid without knowledge of their co-player's identity.

(c) *[Disagreement payoff]: If condition (a) applied to a pair, the participants in that pair would leave the laboratory with the minimum payoff they could individually earn in the game.*[9]

As a matter of fact, such a disagreement payoff was never applied, since all pairs reached an agreement within the 90-minute time limit of condition (a). Only 1 out of the 104 pairs of experimental participants came close to the time limit, reaching an agreement in the 34^{th} period, after the experimenter announced that only 2 minutes remained before the session ended.

Under conditions (a)-(c), the average GCP duration in Study 1 was less than 10 minutes (median agreement period = 2^{nd}).

Study 2

Study 2 was conducted in October 2024, consisting of 16 sessions with a total of 214 participants. Each person could only participate in one of these sessions. None of the participants in Study 2 had previously participated in Study 1. Average earnings were €15.13, including a €5 show-up fee (minimum and maximum earnings were respectively €5 and €21); the average duration of a session was 25 minutes, including instructions, questionnaire, and payments.

Study 2 differed from Study 1 only for conditions (a') and (b') below, replacing (a) and (b) above, respectively. At the start of the experimental session, participants were informed that:

[9] This is in line with the assumption (i) in the theoretical analysis: disagreement is not better than any (confirmed) agreement. In the *Winner-Take-All* (resp., *Sharing*) payoff matrix of Table 1 (resp., Table 2), the minimum payoff each player could get in the game is 0 (resp., 5).

(a') *[Termination rule in case of disagreement] In the absence of a confirmed agreement during any period, the game would conclude with a 2% probability in that period.*

Hence, differently from condition (a) of Study 1, the game did not have a pre-imposed time limit. Following Fréchette and Yuksel [2017], the random termination rule in any period was implemented by the zTree software using a random draw from a uniform distribution of 100 numbers, with 2 of them resulting in the termination of the GCP for all pairs that had not confirmed an agreement in that period.

(b') *[How to leave the lab in case of agreement] If a pair reached an agreement, the participants in that pair would have to wait for all other pairs to leave the laboratory.*

Hence, differently from condition (b) of Study 1, once a pair confirmed an agreement, a message on the screen instructed them to wait calmly until all other pairs confirmed an agreement or the GCP randomly terminated. The experimenters escorted them out of their cubicles only at the end of the session, directing participants belonging to the same pair to separate rooms, where they were individually paid without knowledge of their co-player's identity.

Condition (c) was the same as in Study 1: the disagreement payoff was the minimum payoff that players could individually earn in the game. In Study 2, this condition applied if condition (a') was met, i.e., if the GCP randomly terminated during a period. However, as in Study 1, this disagreement payoff was never applied, as all pairs reached an agreement before the two numbers (out of 100) leading to the termination of the GCP were randomly drawn. Only 1 out of the 107 pairs confirmed an agreement after the 6^{th} period, specifically in the 16^{th} period.

Under varied conditions (a') and (b') and same (c) condition as Study 1, in Study 2 the average GCP duration was less than 5 minutes (median agreement period = 1^{st}).

Treatments and common features among the two studies

Prior to the experiment, subjects were asked to complete a short questionnaire designed to collect personal information (age, sex, study, and work life), their social attitudes (level of social trust and risk preferences), and their level of intuitive thinking. The decision to administer the questionnaire before the decision task (GCP) was motivated by the fact that, in Study 1, pairs were required to leave as soon as they reached an agreement. As a result, the questionnaire was distributed simultaneously to all subjects at the start of the experimental session. For consistency, the same approach was followed in Study 2.

The experiment followed a 2 x 2 between-subjects design with the treatment variables being: (i) whether the game was a *Winner-Take-All* or a *Sharing* GCP; and (ii) whether the confirmation power was symmetric or asymmetric.

In all treatments, at the beginning of the GCP, pairs were randomly formed and remained fixed throughout the experimental game. Within each pair, one player was randomly assigned to the role of proposer, and the other to the role of respondent, for the first period. Each player was informed of their initial role via the computer screen. The identity of the proposer in subsequent periods depended on whether the treatment was *Symmetric* or *Asymmetric*. More specifically:

Winner-Take-All vs. Sharing treatments. In *Winner-Take-All* treatments, subjects played the GCP with the payoff matrix of Table 1. In *Sharing* treatments, they faced the payoff matrix of Table 2.

Symmetric vs. Asymmetric treatments. In *Symmetric* treatments, the player assigned as proposer in the first period of the GCP acted as the proposer in every odd-numbered period, while the other player (the first-period respondent) acted as the proposer in every even-numbered period. In *Asymmetric* treatments, the first-period proposer retained the role of proposer for all subsequent periods.

Observe that Study 1 and Study 2 primarily differ in the termination rule applied when implementing the GCP (condition (a) vs. (a')).[10] Since our GCP is infinite, and it is impossible to faithfully replicate such a condition in a laboratory setting, in Study 1 we ensured that the available time was finite but sufficiently long to avoid putting pressure on the players. The fact that only one pair came close to the time limit, while all others concluded the bargaining much earlier, suggests that setting a maximum time did not influence participants' strategies. In Study 2, by contrast, we implemented a standard termination rule by introducing a fixed probability of continuing the game after each period [Roth and Murnighan, 1978]. This termination rule, commonly used for the implementation of infinite (or infinitely repeated) games, has been shown to generate the highest level of cooperation [Fréchette and Yuksel, 2017].

In what follows, we will refer to the four treatments as *Take-All Symmetric, Take-All Asymmetric, Sharing Symmetric* and *Sharing Asymmetric*. We have a total of 50, 52, 56, and 50 observations for each treatment in the first study, and a total of 52, 54, 54, and 54 observations for each treatment in the second study, respectively.[11]

The sample size was determined based on the methodology of Attanasi et al. [2013], which collected data from 216 participants equally divided into two treatments – *Symmetric* vs. *Asymmetric* – with only one original game (the Prisoner's Dilemma). In our current study, we have a comparable number of participants – 208 for Study 1 and 214 for Study 2 – almost equally distributed across the four treatments, while maintaining a comparable sample size for each variable of investigation:

[10] The additional difference, regarding whether subjects may leave the room as soon as an agreement is reached (condition (b) vs. (b')), was implemented as an improvement to our experimental design, as suggested by an anonymous reviewer.

[11] The difference in the number of participants across the four treatments is due to variations in the show-up rate among experimental sessions. When dealing with variables referred to the outcome of a pair, in the regression tables, we cluster by pair.

Winner-Take-All vs. *Sharing*, and *Symmetric* vs. *Asymmetric*. However, note that subjects played in pairs, meaning the number of independent observations for variables related to the confirmed agreement must be divided by two, leading to 104 independent confirmed agreements in Study 1 and 107 in Study 2.

3.2 Experimental hypotheses

Our experimental hypotheses examine behavioral differences across the four treatments of our bargaining game and are divided into three categories: (1) those addressing the payoff features of agreements, (2) those related to equilibrium agreements, and (3) those concerning the speed at which agreements are confirmed.

The first category (H1) focuses on those features of the confirmed agreement that are related to the structure of the payoff matrix in the original *Winner-Take-All* and *Sharing* games – equitable, welfare-maximizing, and Pareto-efficient outcomes – described in Figure 1, and are not directly theory-driven. As these outcome features are independent of the type of confirmation power of the GCP, we should find no significant difference between its *Symmetric* and the *Asymmetric* version.

According to Figure 1, we should find no significant difference also between *Winner-Take-All* treatments and *Sharing* treatments as to the likelihood of reaching an equitable or welfare-maximizing outcome, since both duopoly games present the same number of both (respectively, 4 equitable and 3 welfare-maximizing outcomes in the corresponding matrix of the original game, regardless of Table 1 and Table 2).

Again relying on Figure 1, given the lower number of Pareto-efficient outcomes in the *Winner-Take-All* game than in the *Sharing* game (3 vs. 9), we expect that in the latter game played with confirmed proposals, the bargaining agreement will more likely be Pareto-efficient. This hypothesis reflects the disparities in payoff structures outside the diagonal of the matrices in Tables 1 and 2, which are inherent to the strategic differences between the two duopoly models under investigation.

With this, we formulate H1.1 - H1.3.

H1.1: *The frequency of equitable agreements is not significantly different between types of confirmation power or between the payoff matrices of the games.*

H1.2: *The frequency of welfare-maximizing agreements is not significantly different between types of confirmation power or between the payoff matrices of the games.*

H1.3: *The frequency of Pareto-efficient agreements is not significantly different between types of confirmation power but is significantly higher in the Sharing treatments compared to the Winner-Take-All treatments.*

The second category of hypotheses (H2) is aimed to validate our theoretical model. The majority of pairs will reach agreements within the set of equilibrium outcomes, i.e., predicted by the theoretical model. The theoretical analysis of Sections 2.1-2.2 show that the set of equilibrium outcomes of the GCP depends on the combination between payoff matrix and confirmation power.

The experimental findings of Attanasi et al. [2013], which we reference in this study, indicate that most confirmed agreements fell within the set of predicted equilibria. However, in their study of the 2×2 Prisoner's Dilemma, the set of predicted equilibria represents 1/4 of the outcomes in the symmetric treatment and 3/4 of the outcomes in the asymmetric treatment. In contrast, as shown in Figure 2, in our 4×4 duopolies, the ratio of equilibrium outcomes to all possible outcomes ranges from 1/16 to 7/16 across the four treatments, making it less straightforward for subjects to play an equilibrium. This emphasizes the relevance of hypothesis H2.1:

H2.1: *The majority of the agreements reached by subjects are equilibrium agreements.*

The second hypothesis on equilibrium agreements is driven by the comparison of predictions of Propositions 1-4, which derive the equilibria of the GCP in the four implementations of the duopolies. Figure 2 shows the existence of a higher number of equilibria in the *Sharing* GCP than in the *Winner-Take-All* GCP, regardless of the type of confirmation power. However, given H2.1, we expect no difference in the equilibrium agreements reached in both games, as the majority of the agreements will be equilibrium ones. This leads to the first part of H2.2.

The second part of H2.2 refines H1.1-H1.3 by addressing the strategic differences between the two duopoly models under investigation. Combining Figures 1 and 2, we observe that the unique equilibrium in the *Winner-Take-All* GCP with symmetric confirmation power, as well as one of the two equilibria in the *Winner-Take-All* GCP with asymmetric confirmation power, simultaneously satisfy the properties of being equitable, welfare-maximizing, and Pareto-efficient. This makes these outcomes more likely to be reached in those treatments compared to the *Sharing* GCP, where, regardless of the type of confirmation power, only 1 out of the 7 (in the symmetric implementation) or 6 (in the asymmetric implementation) equilibria satisfy all three properties.

H2.2: *The frequency of equilibrium agreements does not differ significantly between the Sharing and Winner-Take-All treatments. However, reaching an equitable, welfare-maximizing, and Pareto-efficient equilibrium is more likely in the Winner-Take-All treatments. Both statements hold irrespective of the type of confirmation power.*

The third category of hypotheses (H3) examines the speed at which an agreement is reached and how this speed depends on the aforementioned agreement features. In our setting, the speed of reaching an agreement should be interpreted as the speed of learning the dynamics of the game. Thus, pairs that take more time to reach an agreement are those for whom understanding the strategic situation, its features, and how to coordinate on an outcome proves more challenging.[12]

The first hypothesis in this category is a corollary of H2.2 as for strategic differences between the two duopolies. Given the presence of zero payoffs off the diagonal and the smaller number of subgame perfect Nash equilibria in the *Winner-Take-All* GCP (Figure 2), these equilibria should serve as focal points, enabling the two players to coordinate more quickly.

H3.1: *An agreement is reached faster in the Winner-Take-All treatments.*

The second hypothesis is based on the structure of tacit communication inherent in the GCP, where the set of players' available "sentences" corresponds to the set of strategies in the original game. When players alternate in exerting the power to end the game, communication through bargaining over strategies and confirmed proposals becomes more effective [Attanasi et al., 2013]. This is because both players have the opportunity to reveal their preferences for the strategies they wish to pursue and the payoffs they are unwilling to accept. Building on this, we formulate our final experimental hypothesis.

H3.2: *An agreement is reached faster in the Symmetric treatments.*

4 Results

In this section, we discuss the experimental findings. The results obtained allow us to test the hypotheses introduced in Section 3.2.

4.1 Agreement features and equilibrium agreements

Figure 3 provides a graphical summary of how frequently the confirmed agreements corresponded to each of the 16 payoff cells from Tables 1- 2, presented separately for Study 1 and Study 2, as well as for each treatment: *Take-All Symmetric*, *Take-All Asymmetric*, *Sharing Symmetric*, and *Sharing Asymmetric*. Empty cells represent outcomes that were never selected as final agreement, while blue cells correspond to equilibrium outcomes of the GDP, as defined in Figure 2 in Section 2.3. Below each table, we indicate the frequency of confirmed agreements that fall within the set

[12]The presence of learning is not inconsistent with the assumption that players are impatient. First of all, note that we impose a very mild assumption of impatience, which simply states that at any point in time the individual prefers to reach the agreement earlier if the payoff from the agreement and the continuation payoff in case of no agreement are the same. Moreover, particularly in the presence of multiple equilibrium outcomes, it is not reasonable to expect that subjects coordinate on the same equilibrium without a learning phase, even in the presence of impatience.

of equilibrium outcomes for that GCP. For the *Asymmetric* treatments, as in Figure 2, behavior is reported with player 1 acting as the first proposer in the GCP.

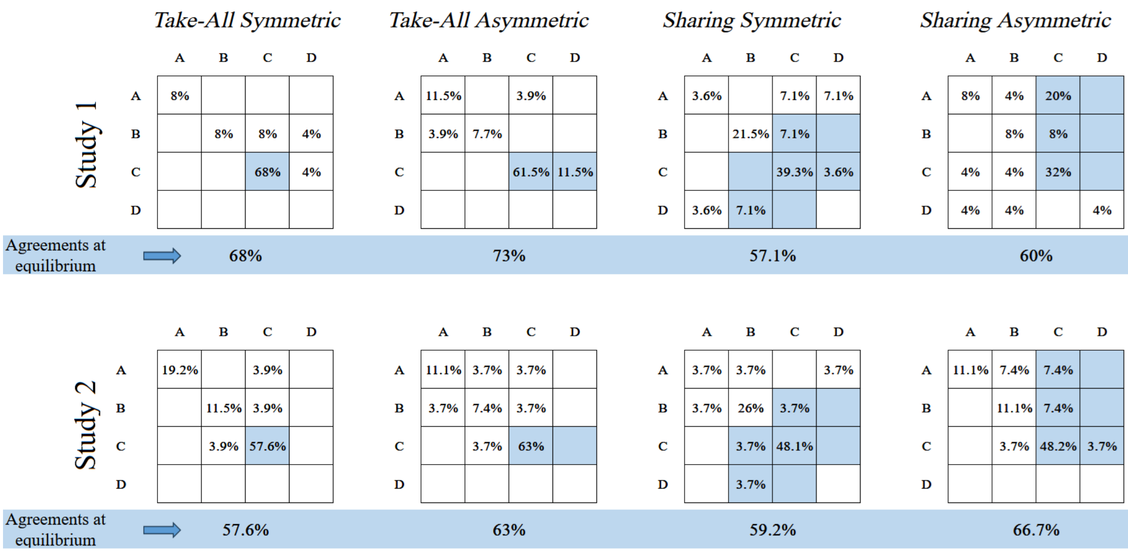

Figure 3: Frequency of each outcome being confirmed as final agreement, and frequency of equilibrium outcomes being confirmed.

Note that slightly more than 50% of pairs confirm the cooperative outcome (C, C) as final agreement. This general pattern is consistent across all treatments and both studies. Even in cases where the equilibrium prediction suggests the possibility of more extreme agreements due to a first-mover advantage – favoring the subject randomly designated as the proposer in asymmetric treatments – such agreements are rarely observed: collectively, they account for less than 15% of observed behavior in asymmetric treatments.

We test our first two categories of hypotheses – those concerning agreement features (H1.1-3) and equilibrium agreements (H2.1-2) – by referring to Figure 4 and Table 3, which provide a deeper analysis of the confirmed agreements reported in Figure 3.

Figure 4 reorganizes the frequencies shown in Figure 3 on the basis of the features of the confirmed agreements. It displays the relative frequencies of confirmed agreements that are equitable, welfare-maximizing, Pareto-efficient, or one of the subgame perfect equilibrium outcomes of the GCP, separately for each of the four treatments where they have been confirmed. Additionally, it highlights the frequency of confirmation of the cooperative agreement (C, C), which uniquely satisfies all the four aforementioned criteria.

Table 3 presents the results of logit regression models applied to the combined data from Study

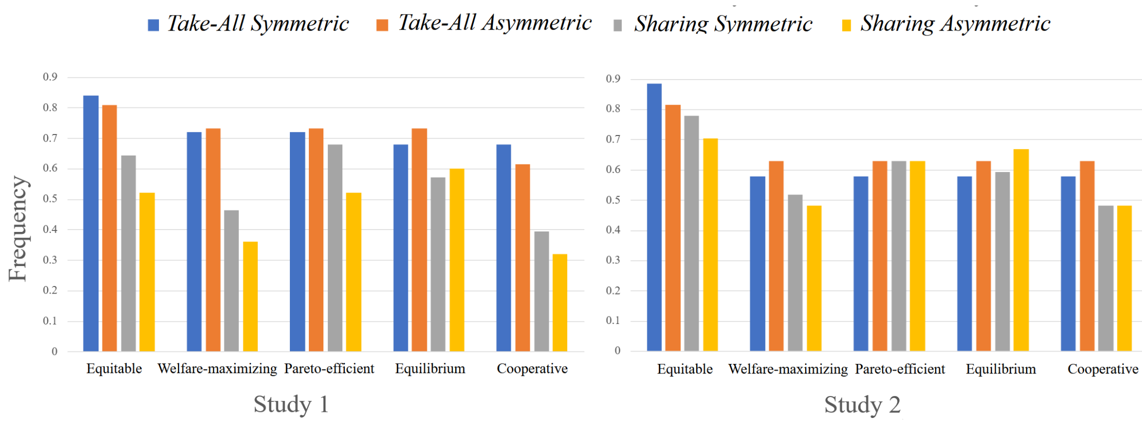

Figure 4: Types of confirmed agreements by Treatment and Study

1 and Study 2.[13] These models are designed to complement the statistics in Figure 4, accounting for subjects' idiosyncratic features and potential effects across the two studies. Following the same order of presentation of Figure 4, the six models predict the likelihood that the confirmed agreement is equitable (Model 1), welfare-maximizing (Model 2), Pareto-efficient (Model 3), one of the subgame perfect equilibria of the GCP (Model 4), or coincides with the cooperative agreement (C, C) (Model 5). Like Model 5, Model 6 also predicts the likelihood that the confirmed agreement coincides with the cooperative agreement (C, C). However, Model 6 focuses on a restricted sample, limited to pairs who confirmed an agreement that corresponds to one of the subgame perfect equilibrium outcomes of the GCP (see Figure 2).

As the 422 subjects in our sample played in fixed pairs, we clustered for subjects' pair, hence the number of independent observations for the confirmed agreements was 211 (half of the subjects). The two main regressors are the two dummy treatment variables, *Take-All* (for the payoff matrix) and *Symmetric* (for the confirmation power). The set of explanatory variables includes a series of controls: the binary variable *Study* (1 and 2) – in order to check whether the different implementations of the game (in)finite length have impacted on the final agreement –, and a series of subjects' idiosyncratic features. *Gender* (1=female, 0=male), *Age*,[14] *Occupation* (1=student, 0=other), *Subject of study* (1=economics, 0=other), *Experience* (number of economic experiments previously attended), self-assessment measures of trust [Guiso et al., 2009], *Trust*,[15] and risk seeking

[13] The results for the same econometric models, including the interaction between the *Take-All* and *Symmetric* dummy variables, are available upon request. These results were not included in the paper, as the first two categories of hypotheses do not clearly predict interaction effects between the two treatment variables. Furthermore, in all six models of Table 3, the interaction coefficient is consistently not significant.

[14] Education level was not included due to its high correlation with age (Spearman's rho = 0.66, *p-value* < 0.001).

[15] Are you a person who generally trust people? On a scale from 0 to 10, how much do you trust people in general (0 meaning "I do not trust people at all," and 10 meaning "I fully trust people")?.

[Dohmen et al., 2011], *Risk*,[16] and the results of three cognitive reflection tests [Frederick, 2005], *CRT*,[17] all elicited through the pre-experimental questionnaire. Regression coefficients in Table 3 refer to the marginal effects of the explanatory variables on the features of the confirmed agreement.

4.1.1 Testing of hypotheses on agreement features

We examine the three hypotheses on agreement features (H1) by implementing pairwise comparisons through χ^2 tests on the distributions of Figure 4, complementing the analysis with the regression models of Table 3.

As for H1.1 (equitable agreements), we find no difference between *Symmetric* and *Asymmetric* treatments (*p-value* $= 0.104$), also by disentangling the two studies (*p-value* $= 0.277$ for Study 1 and 0.200 for Study 2). Significant differences are instead found in favor of the *Take-All* treatments (*p-value* < 0.001), also by disentangling the two studies (*p-value* < 0.001 for Study 1 and *p-value* $= 0.051$ and for Study 2). Model 1 in Table 3 confirms the results of non-parametric testing showing a non-significant coefficient for the *Symmetric* dummy variable and a significant one, at the 1% level, for the *Take-All* dummy variable. Furthermore, the coefficient of *Study* is non-significant, thereby confirming that the two studies yield similar results. We conclude that **H1.1 is not rejected for the type of confirmation power, while it is rejected for the game type.** In fact, differently from what we expected, the frequency of equitable agreements confirmed in the *Winner-Take-All* GCP was higher than in the *Sharing* GCP.

A similar picture emerges when testing H1.2 (welfare-maximizing agreements). We find no difference between *Symmetric* and *Asymmetric* treatments (*p-value* $= 0.778$), also by disentangling the two studies (*p-value* $= 0.602$ for Study 1 and 0.902 for Study 2). The difference in favor of the *Winner-Take-All* treatments (*p-value* < 0.001) remains significant only for Study 1 (*p-value* < 0.001 for Study 1 and *p-value* $= 0.128$ and for Study 2). However, Model 2 in Table 3 shows that the coefficient of *Study* is not significant and confirms the significance of the *Take-All* dummy variable at the 1% level. We conclude that **H1.2 is not rejected for the type of confirmation power, while it is rejected for the game type.** Again, differently from what we expected, the frequency of welfare-maximizing agreements confirmed in the *Winner-Take-All* GCP was higher than in the *Sharing* GCP.

[16] Are you a person who generally likes to take risks? On a scale from 0 to 10, how much are you ready to take risks (0 meaning "I do not want to take any risk" and 10 meaning "I am fully ready to take risks")? (adapted by Bernasconi et al. [2014] from Dohmen et al. [2011]).

[17] The variable *CRT* is the sum of correct answers to the three following questions: Q1) A bat and a ball cost 1.10 euros in total. The bat costs 1.00 euro more than the ball. How much does the ball cost? Q2) If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? Q3) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?

Table 3: Logit regression models predicting the likelihood that the confirmed agreement is equitable (1), welfare-maximizing (2), Pareto-efficient (3), an equilibrium (4), the cooperative agreement (5), and the cooperative agreement conditionally to an equilibrium being played (6)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Take-All	1.004***	0.872***	0.213	0.224	0.846***	2.456***
	(0.344)	(0.289)	(0.291)	(0.291)	(0.286)	(0.656)
Symmetric	0.440	0.092	0.126	-0.161	0.117	0.792
	(0.345)	(0.294)	(0.295)	(0.294)	(0.291)	(0.524)
Study	0.532	-0.151	-0.276	-0.179	0.140	1.073*
	(0.342)	(0.292)	(0.296)	(0.296)	(0.291)	(0.565)
Gender	0.048	-0.189	-0.037	0.198	-0.070	-0.684
	(0.284)	(0.234)	(0.234)	(0.231)	(0.229)	(0.437)
Age	0.031*	0.019	0.011	0.013	0.021	0.023
	(0.018)	(0.017)	(0.018)	(0.018)	(0.017)	(0.023)
Occupation	0.753**	0.698*	0.434	0.240	0.740**	1.495***
	(0.379)	(0.360)	(0.366)	(0.370)	(0.360)	(0.527)
Subject of study	-0.364	-0.071	0.003	0.020	-0.055	-0.201
	(0.259)	(0.224)	(0.222)	(0.225)	(0.222)	(0.354)
Experience	0.016	0.051	0.040	0.054	0.036	-0.001
	(0.044)	(0.037)	(0.037)	(0.037)	(0.037)	(0.063)
Trust	0.076	0.093*	0.082	0.102*	0.087	0.081
	(0.061)	(0.053)	(0.052)	(0.053)	(0.054)	(0.103)
Risk	-0.032	-0.095**	-0.066	-0.053	-0.076	-0.052
	(0.060)	(0.048)	(0.049)	(0.049)	(0.047)	(0.100)
CRT	0.037	0.017	0.036	-0.002	-0.034	-0.187
	(0.116)	(0.099)	(0.105)	(0.101)	(0.097)	(0.185)
Constant	-1.854*	-1.034	-0.018	-0.286	1.782*	-2.329
	(1.067)	(0.936)	(0.968)	(0.964)	(0.948)	(1.736)
Observations	422	422	422	422	422	266
Wald χ^2	19.85**	21.37**	7.46	9.98	19.25*	31.85***
Pseudo R^2	0.073	0.054	0.016	0.020	0.049	0.236

Standard errors clustered at the pair level are reported in parenthesis.
*** p<0.001 ** p<0.01, * p<0.05

When testing H1.3 (Pareto-efficient agreements), we report no difference between *Symmetric* and *Asymmetric* treatments (*p-value* = 0.633), also by disentangling the two studies (*p-value* = 0.282 for Study 1 and 0.698 for Study 2). The same occurs when comparing the *Take-All* and *Sharing* treatments (*p-value* = 0.320), also by disentangling the two studies (we report a small significance with *p-value* = 0.064 for Study 1 but not for Study 2, where *p-value* = 0.698). Model 3 in Table 3 confirms these results, as none of the main explanatory variables, *Take-All* or *Symmetric*, nor the variable *Study*, has a significant coefficient in the regression. We conclude that **H1.3 is not rejected for the type of confirmation power, while it is rejected for the game type.** In fact, differently from what we expected, the frequency of Pareto-efficient agreements confirmed in the *Winner-Take-All* GCP was not lower than in the *Sharing* GCP.

4.1.2 Testing of hypotheses on equilibrium agreements

We examine the two hypotheses driven by our equilibrium model (H2) by non-parametric tests on the distributions of Figures 3 and 4, complementing the analysis with the regression models of Table 3.

We test H2.1 by looking at the frequency of agreements at equilibrium shown in Figure 3 and in fourth cluster of bars (Equilibrium) in each panel of Figure 4. The frequency of equilibrium outcomes is significantly higher than 50%, and this holds by pooling all observations (63.03%, two-sided Binomial exact test: *p-value* < 0.001) and for the two studies separately (64.42%, *p-value* < 0.001 for Study 1; 61.68%, *p-value* = 0.001 for Study 2). This significance persist when we disentangle per treatment (62.75%, *p-value* < 0.001 for *Winner-Take-All Symmetric*; 67.92%, *p-value* < 0.001 for *Winner-Take-All Asymmetric*; 63.46%, *p-value* = 0.008 for *Sharing Asymmetric*), apart for the *Sharing Symmetric* treatment (58.18%, *p-value* = 0.105). Model 4 in Table 3 confirms no difference across either treatments or studies, since the coeffients of all variables *Take-All*, *Symmetric* and *Study* are non-significant. We conclude that **H2.1 is not rejected**.

When testing H2.2, we first observe that there is no significant difference in the frequency of equilibrium agreements between the *Winner-Take-All* and *Sharing* treatments (χ^2 test, *p-value* = 0.324). This finding holds when analyzing the two types of confirmation powers separately (*p-value* = 0.257 for the *Symmetric* treatment and *p-value* = 0.593 for the *Asymmetric* treatment). Model 4 in Table 3 supports this result, as the coefficients of both *Take-All* and *Symmetric* are not significant. When the two studies are analyzed separately, we find a significant difference in the frequency of equilibrium agreements in favor of the *Winner-Take-All* game for Study 1 (*p-value* = 0.069), but not for Study 2 (*p-value* = 0.698). However, the coefficient for *Study* is not significant in Model 4 of Table 3, indicating that the frequency of equilibrium agreements does not depend on the Study. Based on this evidence, we conclude that **the first part of H2.2 is not rejected**.

As for the second part of H2.2, under the assumption that a pair reaches an equilibrium agreement, the likelihood of achieving the cooperative outcome – which is simultaneously equitable, welfare-maximizing, and Pareto-efficient – favors the *Winner-Take-All* treatments (95.59% vs. 69.23%, χ^2 test: *p-value* < 0.001). This result holds regardless of the type of confirmation power (*p-value* < 0.001 in the *Symmetric* treatment; *p-value* < 0.001 in the *Asymmetric* treatment). It also persists when the two studies are analyzed separately (*p-value* < 0.001 for Study 1, and < 0.001 for Study 2). Model 6, with its significant coefficient for *Take-All* and non-significant coefficients for *Symmetric* and *Study*, confirms the findings of the non-parametric tests. Notably, the coefficient for *Take-All* remains significant even when the entire sample is considered, including pairs that confirmed out-of-equilibrium agreements (Model 5). This persistence is explained by the magnitude of the *Take-All* coefficient in Model 6, which is sufficiently large to retain significance in Model 5. Based on these results, we conclude that **the second part of H2.2 is not rejected**.

4.2 Speed of agreement

We conclude the analysis by testing the final category of hypotheses presented in Section 3.2. We examine the speed of agreement for each pair using two measures: the number of periods required to reach an agreement (Figure 5) and the actual bargaining time, measured in seconds (Table 4).

Figure 5 displays the distribution of agreement periods across the four treatments, separately for Study 1 and Study 2. The color code of each treatment is the same as in Figure 4.

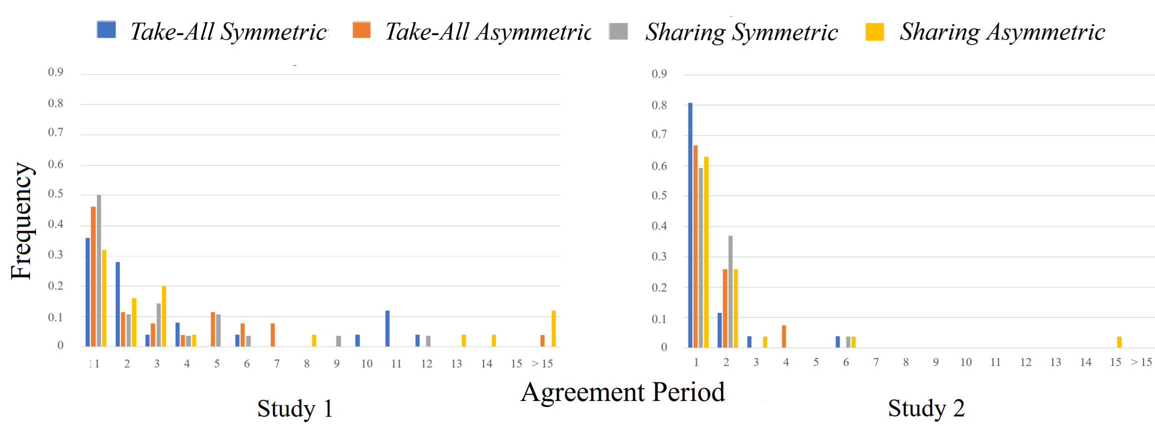

Figure 5: Distribution of agreement periods by Treatment and Study

Table 4 presents the results of OLS regression models applied to the entire sample (Study 1 and Study 2), with the effective agreement *Time*, measured in seconds, as the dependent variable.

Table 4: OLS regression models predicting the agreement time considering all (Model 1), equitable (Model 2), welfare-maximizing (Model 3), Pareto-efficient (Model 4), equilibrium (Model 5) and cooperative confirmed agreements (Model 6)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Take-All	-119.525*	8.679	-49.193	-147.376	-175.082*	-35.511
	(71.534)	(64.115)	(77.089)	(102.475)	(99.315)	(82.019)
Symmetric	-150.701**	-48.080	-98.206	-198.592**	-228.033**	-100.086
	(67.475)	(57.132)	(69.828)	(96.525)	(91.729)	(73.723)
Take-All#Symmetric	154.244*	38.701	87.577	183.149	219.258*	73.458
	(83.445)	(80.853)	(94.078)	(116.762)	(113.962)	(100.096)
Study	-209.041***	-204.766***	-227.672***	-243.435***	-249.088***	-254.229***
	(42.410)	(42.213)	(47.535)	(57.275)	(58.446)	(53.705)
Gender	36.026	4.249	16.054	51.871	43.031	4.431
	(27.152)	(22.901)	(27.251)	(37.122)	(36.446)	(28.717)
Age	-3.781*	-2.434	-4.547*	-6.151*	-6.127*	-4.649*
	(2.154)	(1.716)	(2.329)	(3.205)	(3.272)	(2.464)
Occupation	-57.622	-9.609	-75.653	-134.942	-97.715	-81.357
	(62.728)	(48.151)	(53.720)	(91.274)	(88.393)	(59.289)
Subject of study	3.880	-14.321	-14.533	-23.109	-9.073	-19.233
	(24.331)	(25.854)	(31.957)	(31.888)	(35.540)	(34.153)
Experience	1.720	4.184	3.969	1.841	0.019	4.450
	(4.844)	(4.982)	(5.869)	(6.385)	(6.912)	(6.632)
Trust	3.664	1.296	1.284	7.556	6.517	3.089
	(8.451)	(10.393)	(12.548)	(11.581)	(12.190)	(13.169)
Risk	24.953***	18.179***	25.822***	39.855***	39.611***	26.503***
	(8.924)	(5.673)	(7.409)	(13.345)	(12.935)	(7.673)
CRT	2.044	-1.279	-20.659	-12.077	-13.445	-17.943
	(15.810)	(11.518)	(14.575)	(23.558)	(24.146)	(15.917)
Constant	605.667	495.540***	668.990***	750.299***	763.488	713.236***
	(141.458)	(113.668)	(138.831)	(200.005)	(202.960)	(147.129)
Observations	422	316	236	270	266	220
F-test	3.11***	2.75***	3.23***	2.26**	2.25**	3.32***
R^2	0.171	0.186	0.224	0.228	0.235	0.245

Standard errors clustered at the pair level are reported in parenthesis.
*** p<0.001 ** p<0.01, * p<0.05

The explanatory variables are the same as those in Table 3, including the two treatment dummies, while controlling for the *Study* dummy and the players' idiosyncratic features elicited through the pre-experimental questionnaire. For the *Take-All* dummy, the reference group includes all pairs in the two *Sharing* treatments; for the *Symmetric* dummy, the reference group includes all pairs in the two *Asymmetric* treatments. Both H3.1 and H3.2 hypothesize a treatment effect, predicting a higher speed of agreement in the *Take-All* and *Symmetric* treatments, respectively. Consequently, we included the interaction between the two treatment dummies as an additional regressor. Model 1 considers all confirmed agreements, encompassing all subject pairs. Model 2 focuses on the subsample of pairs that confirmed an equitable agreement. Similarly, the other models restrict the sample to pairs that confirmed a welfare-maximizing (Model 3), a Pareto-efficient (Model 4), an equilibrium (Model 5), or the cooperative agreement (Model 6).

Non-parametric tests on the distribution of agreement periods reported in Figure 5 provide weak support for both H3.1 and H3.2. Specifically, as hypothesized, we observe a lower average agreement period in the *Take-All* treatments (2.52 vs. 3.08) and in the *Symmetric* treatments (2.37 vs. 3.25). However, neither of these differences is statistically significant (Mann-Whitney test, *p-value* = 0.243 and 0.216, respectively). The same result holds when disentangling by *Study*.[18] This result is likely due to the left-skewed distribution of agreement periods, particularly in Study 2. Indeed, the highest and lowest median agreement periods per treatment are 2 and 1, respectively, both of which coincide with 1 when conditioning on Study 2.

However, recall that we gave pairs 180 seconds per period, with 80 seconds for each proposal and 20 seconds for the confirmation choice. Therefore, given the same number of played periods, we could have pairs who coordinated faster and others who took a long time to agree on an outcome. This naturally calls for the analysis in Table 4, based on the actual time needed to reach an agreement, which is a much less coarse measure than the number of periods played.

Table 4 shows that both *Take-All* and *Symmetric* treatments have a significant negative effect on agreement time in Model 1 and Model 5, i.e., when considering all pairs and when restricting the analysis to those confirming an equilibrium agreement. However, their interaction term has a positive coefficient in both models, suggesting that the combined presence of these two treatments offsets the negative effects observed when each is considered individually. Additionally, the *Symmetric* dummy exhibits greater significance than the *Take-All* dummy in both models and also shows a significant effect in Model 4, i.e., when restricting the analysis to pairs confirming a Pareto-efficient agreement. Based on these findings, we conclude that **H3.1 is not rejected considering all confirmed agreements, and for the subset of equilibrium ones**. **H3.2 is not rejected considering all final agreements, and for the subsets of equilibrium and Pareto-efficient ones**.

We conclude the analysis by examining the control variables (*Study* and participants' characteristics). Figure 5 demonstrates that the number of periods required to confirm an agreement is significantly higher in Study 1 compared to Study 2 (Mann-Whitney test, *p-value* < 0.001).

[18] The only exception is the comparison between *Take-All* and *Sharing* treatments in Study 2 (*p-value* = 0.072).

Specifically, in Study 1, participants reached a final agreement in an average of 4.03 periods (median = 2), whereas in Study 2, agreements were finalized in an average of 1.62 periods (median = 1). This difference also remains statistically significant when considering bargaining time (t-test, *p-value* < 0.001). Furthermore, Table 4 indicates that the coefficient for *Study* is statistically significant across all models, confirming that participants in Study 2 reached agreements more quickly. We attribute this difference to the implementation of the termination rule in Study 2 (condition (a'), Section 3.1). Specifically, despite the very low probability of the GCP not progressing to the next period in the case of no confirmation (2%), we suggest that this rule may have encouraged participants to reach agreements earlier to avoid the lower disagreement payoff. It is important to highlight that this is the first instance where we observe a pronounced effect of *Study*. While the different implementations of the theoretical model in Study 1 and Study 2 influenced the time required to reach an agreement, they did not affect the nature of the agreements themselves (see Section 4.1).

Regarding players' idiosyncratic features in Table 4, it is worth noting that –regardless of the confirmed agreement – risk-seeking preferences have a significant positive effect on the length of the bargaining process. This finding aligns with the experimental literature, which reports a negative correlation between risk and time preferences, suggesting that risk-seeking individuals tend to be more patient and more willing to defer consumption [see, e.g., Ferecatu and Önçüler, 2016]. Notably, this is the first and only instance in which individual heterogeneity emerges in our results. Indeed, the results in Table 3 indicate that none of the participants' idiosyncratic features influenced the nature of the confirmed agreements.

5 Conclusions

In this paper, we analyzed, both theoretically and experimentally, a bargaining over strategies protocol with confirmed proposals. This bargaining model is inspired by the seminal work of Rubinstein [1982] and was first implemented by Attanasi et al. [2013]. Amnon Rapoport and his coauthors highlighted the importance of experimentally studying alternative bargaining models, applying them to more realistic and sophisticated economic problems compared to the traditional ultimatum game [see, e.g., Rapoport et al., 1990, Weg et al., 1990, Rapoport et al., 1995, Rapoport and Sundali, 1996, Weg et al., 1996]. Following this approach, we were the first to apply the bargaining model with confirmed proposals to the context of duopoly markets, where price-setting experiments have reported a higher frequency of collusion compared to quantity-setting experiments Suetens and Potters [2007].

In this context, we considered a discretized Bertrand and a discretized Cournot duopoly, stripped of their respective price- and quantity-setting frames. These were defined to exhibit the same collusive outcome and the same set of equitable and of welfare-maximizing agreements on the diagonal of the game matrix. The two duopolies differed in their structure outside the diagonal, in the set of Pareto-efficient outcomes, and, naturally, in their Nash equilibrium outcomes. Based on the payoff structures of these two matrices, we redefined the duopolies as, respectively, *Winner-Take-All* and *Sharing* games.

We first qualitatively analyzed the payoff features of the collusive/cooperative agreement in the two discretized duopolies, highlighting that it is the only outcome simultaneously equitable, welfare-maximizing, and Pareto-efficient in both the *Winner-Take-All* and the *Sharing* games. We then identified the set of equilibria in the game with confirmed proposals applied to the strategies available in the original *Winner-Take-All* and *Sharing* games. Following Attanasi et al. [2013], we implemented the bargaining protocol under both *Symmetric* (alternating) and *Asymmetric* (one-player-only) power of confirming the proposed strategy profile.

Our theoretical analysis showed that the cooperative agreement could always be sustained as a subgame perfect equilibrium outcome in both the *Winner-Take-All* and *Sharing* games, regardless of the type of confirmation power. Furthermore, there is a larger set of equilibrium outcomes when the original game is the *Sharing* game, regardless of the type of confirmation power. Additional inequitable agreements emerge as equilibrium outcomes in the *Asymmetric* treatments.

Building on our qualitative analysis of the features of the *Winner-Take-All* and *Sharing* matrices, we formulated hypotheses regarding treatment differences in the frequency of equitable, welfare-maximizing, and Pareto-efficient agreements confirmed through bargaining with confirmed proposals (H1). Based on our theoretical predictions, we also hypothesized treatment differences in the frequency of equilibrium agreements (H2) and the speed at which they would be confirmed (H3). These hypotheses were tested in two comparable experimental studies involving more than 200 pairs of participants as a whole.

The experimental results showed that H1 performed well when considering the type of confirmation power (*Symmetric* or *Asymmetric*). This primarily served as a control, as the payoff features (equitable, welfare-maximizing, Pareto-efficient) of the available agreements are independent of the type of confirmation power. Instead, they depend solely on the strategic characteristics of the original duopoly games. Consequently, when holding the payoff matrix constant, the distribution of confirmation power had no substantial effect on the frequency of agreements with specific payoff features. However, H1 did not perform well when considering the game type (*Winner-Take-All* or *Sharing*). Behavioral differences aligned with differences in the payoff matrices between the two duopoly games, with a higher frequency of equitable and welfare-maximizing agreements being confirmed in the *Winner-Take-All* game – despite the cardinality of these sets being identical across the two games.

This result is relevant as it provides initial evidence supporting the superiority of the price-setting duopoly over the quantity-setting duopoly in fostering cooperative behavior among firms.

At the same time, it underscores the importance of accounting for players' behavioral responses to differences in payoff matrices within a theoretical model – an approach we adopted when formulating H2.

The successful test of H2 represents the most important result of our experimental study. Our equilibrium predictions were upheld in more than half of the sample, with equilibrium agreements being reached at similar frequencies across both duopoly types. However, the likelihood of these agreements coinciding with the cooperative outcome was significantly higher in the *Winner-Take-All* game, both with and without conditioning on equilibrium play. Thus, the higher frequency of cooperative agreements in the *Winner-Take-All* game cannot be attributed to a higher frequency of equilibrium play in this game. We interpret this as strong evidence supporting the relevance of our game-theoretical model in explaining the differing strategic incentives between the two duopolies.

Also, H3 performed well. Consistent with our theoretical predictions, bargaining on the *Winner-Take-All* matrix and using *Symmetric* power of confirmation were each found to have a positive effect in reducing the bargaining length. Regarding the former, we observe that learning processes are easier in the context of a *Winner-Take-All* game, where extreme payoffs simplify strategic considerations. This finding may also be linked to a form of conservative behavior, where participants avoid exploring alternative strategies in the early periods of the game, particularly when relative losses could be significant (*Winner-Take-All* treatments). As for the effect of alternating confirmation power, tacit communication within the confirmed proposal mechanism is more efficient when players can elicit their opponent's intentions while alternating between proposer and counterproposer roles. Finally, among the four features characterizing the collusive agreement – equitable, welfare-maximizing, Pareto-efficient, and equilibrium – these two findings hold together only when conditioning the analysis on equilibrium agreements.

We interpret this as further evidence of the relevance of our theoretical model in capturing strategic differences in duopoly games under the standardized interaction facilitated by bargaining with confirmed proposals.

In this regard, our work extends Attanasi et al. [2013] in three key dimensions. First, we replicate their findings on high cooperation rates and speed of confirmation in a much more complex strategic environment (discretized duopoly vs. Prisoner's Dilemma). Second, we show that the remarkably high cooperation rate they observed in their 2x2 social-dilemma matrix is similarly high in 4x4 social dilemmas, provided the latter retain features such as a small number of Pareto-efficient and equilibrium agreements (*Winner-Take-All* dilemmas), which serve as focal points. Finally, we demonstrate that equilibrium predictions become increasingly relevant in capturing subjects' behavior when bargaining involves larger sets of strategy profiles.

The last consideration calls for an extension of our study. The theoretical analysis in this paper focused on specific game forms, which were then used for experimental data collection and analysis. However, the insights derived from these specific cases are also informative for more general scenarios where duopolists have larger (finite) sets of prices or quantities to choose from, or face varying demands or marginal costs. First, the finding that proposers (resp., respondents) achieve higher (resp., lower) equilibrium payoffs under asymmetric compared to symmetric confirmation power is generalizable. Second, price-setting duopolies are likely to have fewer equilibrium outcomes than quantity-setting duopolies, primarily due to the presence of zero-payoffs off the diagonal. Notably, the cooperative outcome will always remain an equilibrium outcome in games with confirmed proposals. Consequently, we expect the second and third categories of hypotheses (H2, H3) to hold even across other dyads of price-setting vs. quantity-setting duopolies, although the specific characterization of equilibrium outcomes may vary. We leave this extension for future research.

Similarly, a systematic study of the role of players' idiosyncratic features in explaining behavior in bargaining games with confirmed proposals offers a promising avenue for further research. Among the individual traits that could influence behavior, an external measure of impatience may help distinguish between "procrastinators", who take longer for each decision, and "no-brainers", who decide quickly. This differentiation could reveal how these types influence final agreements, particularly in relation to their distribution across treatments.

Finally, a deeper analysis of the sequence of proposals, counterproposals, and (non-)confirmation in bargaining could provide valuable insights into the behavioral factors driving players' decisions and the dynamics leading to specific types of final agreements. For instance, a drastic change in the sub-sequences of proposals and counterproposals across bargaining periods within the same pair might indicate that preferences between two agreements during the same bargaining period depend on past history, thus challenging our assumption of preference stationarity. This could be attributed to shifts in the perception of fairness or the emergence of reciprocity behaviors during bargaining dynamics [Bolton and Ockenfels, 2000]. More broadly, a within-subject analysis of bargaining dynamics could shed light on the influence of players' social preferences on outcomes [see, for example, Ferrario and Manzoni, 2022], or reveal the effects of unequal power distribution among players involved in bargaining [see, for example, Chessa et al., 2023]. This extension would require incorporating incentivized tasks designed to elicit players' social preferences. We leave this line of inquiry for future research.

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