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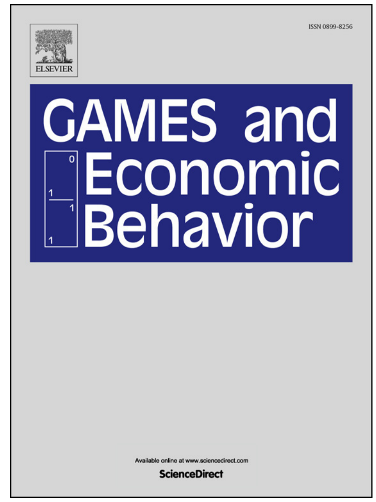

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Highlights

- We experimentally consider a tacit bargaining situation.
- Players earn and cumulate their payoffs in real time.
- We vary the focality of payoffs, and how complex it is to coordinate on them.
- Both payoff focality and coordination complexity shape observed behavior.

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Real-Time Tacit Bargaining, Payoff Focality, and Coordination Complexity: Experimental Evidence*

Wolfgang Luhan† Anders Poulsen‡ Michael Roos§

March 13, 2017

Abstract

We conduct a bargaining experiment where interaction is tacit and payoffs are earned and cumulated in real time. We test hypotheses about the interaction between the focal properties of payoffs and the complexity of coordinating on an intertemporal behavior that achieves them. The general finding is that when a payoff focal outcome requires a complicated coordination scheme bargainers tend to settle on a simpler and sometimes inefficient behavior.

Keywords: bargaining; payoff focality; coordination complexity.

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> The study of tacit bargaining – bargaining in which communication is incomplete or impossible – assumes importance, therefore, in connection with limited war, or, for that matter, with limited competition, jurisdictional maneuvers, jockeying in a traffic jam, or getting along with a neighbor that one does not speak to. (Schelling (1960), p. 53)

1 Introduction

In this paper we report the findings from an experiment that aims to capture bargaining environments with the following features. First, decisions are *non-cooperatively* made in *real time*—the players cannot sign binding contracts that regulate their current and future behavior, and there are no externally imposed constraints on how often players can revise their decisions. Second, there is a surplus that consists of one or more *indivisible items* (such as parcels of land, fishing spots, or geographically distinct sales districts).[1] The surplus renews continuously, and the players' chosen actions generate payoffs that they *immediately* receive and *cumulate* over the time period. Third, the stage game played at every time instant has multiple Nash equilibria, and the players prefer different equilibria. Finally, interaction is *tacit* – the players can not communicate via cheap talk (see, e.g., Farrell and Rabin (1996) and Schelling (1960)).

Let us describe some real world situations with the features described above.

Duopoly Two firms, producing an identical good and selling it in two geographically separated markets, choose non-cooperatively, tacitly, and in real time how much to offer for sale in each market, and cumulate profits over time. Each market can only sustain one firm, and markets differ in profitability.

Neighbors Two neighbors who cannot or prefer not to talk (cf the quote from Schelling above) decide when and for how long to use a shared out-

[1] Rather than consisting of items that are physically indivisible, we may think of the surplus as consisting of divisible objects that, due to complementarities in production or consumption, are of use only if certain quantities are held by the same player.

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door area, playground, and parking area. Each facility has capacity for a single user only, or the neighbors prefer not to meet at the same place.

Common pool resource Fishermen from different villages who do not communicate with each other decide in real time which fishing spots to occupy and for how long (this is a common pool resource situation—see Ostrom et al. (1994)). Each fisherman prefers to get a fishing spot for him or herself, but if several fishermen try to take the same spot, there will be a costly dispute.

These situations are not 'standard' negotiation situations—no discussion takes place around a negotiation table, there is no exchange of offers and counteroffers, and no contracts are signed. Nevertheless, our environment has an essential element of bargaining at its core, since there are many possible ways the players can divide the assets between them over the time period, and there is a conflict of interest (each would like to consume all the resources at every moment in time); and a failure to 'agree' (which in our context means that the assets are in dispute) leads to an inferior outcome for all players. However the players are not only faced with the problem of tacitly agreeing on which overall payoffs they should aim for – they need to coordinate on an intertemporal behavior that achieves these overall payoffs. There are many of these, so this amounts to solving a coordination problem. Thus the players effectively face both a bargaining and a coordination problem, and both must be tackled simultaneously, tacitly, and in real time.[2]

We focus on two aspects that we thought would be important in a real-time tacit bargaining environment. First, a well-known hypothesis is that bargainers may be able to coordinate on a focal outcome of the game (see Isoni et al. (2014), Roth (1985), Roth (1995), and Schelling (1960)).[3] We expected that payoff-based sources of focality (*payoff focality*), such as equal-

[2]We thank a reviewer and the Associate Editor for their comments which helped us to clarify the relationship between the bargaining and coordination element.

[3]In general, sources of focality include symmetry, payoff efficiency, payoff equality, total payoff maximization, earned entitlements, and historical precedent (see for example Van Huyck et al. (1990) and Huyck et al. (1992), Anbarci and Feltovich (2013), Anbarci and Feltovich (2016), Gächter and Riedl (2005), Galeotti et al. (2016), Isoni et al. (2013), Isoni et al. (2014), Janssen (2006), Roth and Murnighan (1982), Schelling (1960), Sugden (1986), and Young (1993)). There is also an experimental literature on 'label salient' focal points; see Blume and Gneezy (2000), Blume and Gneezy (2010), Crawford et al. (2008), Isoni et al. (2013), and Isoni et al. (2014).

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ity, efficiency, and total payoff maximization, would influence behavior.[4]

Second, we conjectured that the complexity of coordinating on an intertemporal behavior that achieves the focal payoffs (*coordination complexity*) would also be behaviorally relevant.

We observe that high coordination complexity is detrimental to coordination. Also, bargainers tend to settle on equal and inefficient payoffs if the behavior giving equal and efficient payoffs is too complex. Furthermore, coordination complexity affects how bargainers trade off equality and efficiency.

These findings strongly suggest that we cannot expect outcomes of real-world ongoing tacit bargaining situations to be efficient, if efficiency requires an intertemporal behavior that is too complex relative to other behaviors that give inefficient but reasonable payoffs. Moreover, we can not deduce bargainers' efficiency and equality concerns from their observed behavior, since this also depends on coordination complexity.

We are, to the best of our knowledge, the first to report experimental data for real time bargaining situations, but there are clear connections to several other research areas.[5] A recent group of papers study strategic environments where decisions are made and payoffs earned in real (effectively, continuous) time. See, for example, Bigoni et al. (2015), Friedman et al. (2004), Friedman et al. (2015), Friedman and Oprea (2012), Oprea et al. (2011), and Oprea et al. (2014), but as far as we know no study considered bargaining situations.[6]

We also contribute to the experimental bargaining literature by considering a setting where players make moves and earn payoffs in real time. We can interpret this as an environment where there are no property

[4]In this paper "efficiency" means Pareto-efficiency, measured in money terms. A "total payoff maximizing outcome" maximizes the sum of players' money earnings. Such an outcome is efficient, but the converse is not true. As an example, consider two Player 1 and 2 money divisions, $(6, 6)$ and $(5, 10)$. Both are efficient, but only the latter maximizes total payoffs.

[5]In his book, *The Strategy of Conflict* (1960), Thomas Schelling gives a general discussion of tacit bargaining situations (see for example p. 102–108) and describes in Schelling (1961) an experimental design where pairs of subjects tacitly decide which parts of the United States to occupy. Some preliminary experimentation was done but no data were published (Schelling, personal communication).

[6]In Camerer et al. (2015) and Galeotti et al. (2016) players make proposals in real time, but earnings are not cumulated over time, and an agreement is assumed to be binding and terminates interaction.

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rights, or they are not enforced. There is no third party who can impose and enforce some notion of 'agreement' (or an exogenous disagreement outcome), and who can prevent players from claiming parts of the surplus whenever they wish.

There are also several important differences between the environment studied in the current paper and those considered in the experimental and theoretical literature on cooperative behavior in repeated games (see, for example, Bhaskar (2000), Bjedov et al. (2016), Bornstein et al. (1997), Cason et al. (2013), Evans et al. (2015), Kaplan and Ruffle (2012), Kuzmics and Rogers (2012), Kuzmics et al. (2014), Lau and Mui (2008), and Lau and Mui (2012)). First, unlike these studies our bargaining environment has no exogenous period structure with simultaneous moves in each period. Second, while many of these studies typically restrict attention to symmetric 2×2 stage games, such as Battle of the Sexes or Prisoner's Dilemma, where a quite simple efficient intertemporal behavior is focal (namely, alternate such that each player gets his preferred outcome in every other period), we consider stage games with asymmetric payoffs and more than two (namely four) strategies. This creates a strategic environment with qualitatively new features. More precisely, the time proportions with which different stage game outcomes need to be coordinated on in order to generate equal and efficient payoffs of the overall game differ from one-half. Furthermore, the stage game can offer an equal payoff outcome that is efficient among the pure stage game payoffs but strictly dominated by an equal and efficient payoff pair of the overall game. We observe that many bargainers settle on the former outcome, which we attribute to its lower coordination complexity. These findings have, as far as we know, no counterparts in the existing literature.

2 The Bargaining Environment

2.1 The Bargaining Stage Game

There are one or two indivisible assets, each with some strictly positive value to each player. When there is a single asset, players simultaneously decide to claim or not to claim the asset. In the case of two assets, each player claims one of the assets, both assets, or neither. If a player is the only one to claim an asset, then he or she gets it. If both players claim an

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asset (it is in *dispute*), no one gets it.[7] The assets can be valued differently by the players. A player who holds an asset receives the value of the asset. The number and values of the assets are common knowledge.[8]

This bargaining stage game has several Nash equilibria. With two assets it is an equilibrium that each player claims a different asset, as is the outcome where one player claims one asset and the other asset is in dispute, as well as each player claiming both assets. There are also many mixed equilibria. In the single asset case it is an equilibrium that the asset is claimed by only one player, or by both players. It can be verified that for each player the strategy of claiming all assets weakly dominates any other strategy. The only undominated equilibrium of the stage game is thus where each player claims all assets and equilibrium payoffs are zero.

2.2 The Repeated Bargaining Game

The bargaining period has a fixed and commonly known length, which in the experiment equals 240 seconds. The computer takes a reading every 1/10 of a second. There are thus 2400 periods.

In each period the players simultaneously choose a pure strategy in the bargaining stage game and get the corresponding payoffs. In what follows, "strategy" always means a pure stage game strategy. Overall payoffs is the undiscounted sum of the period payoffs. Subjects did not have to choose a strategy every period (this would clearly be physically impossible given the very short period length); they only had to submit a new strategy when they wished to *change* their currently submitted strategy, and they could do this as often as they wished.

The repeated game has a large set of Nash equilibria (as is the case for most finitely repeated games; see, e.g., Fudenberg and Tirole (1991) and Mailath and Samuelson (2006)) which differ in their efficiency and

[7]Our assumption that conflict over an asset completely destroys its value for both players is admittedly extreme. In practice there may still be some sharing of the asset, as in our motivating examples. And, as was pointed out by a reviewer, while values are reduced by dispute the original holder may still earn more than the new claimant. The important thing, however, is that conflict over an asset leads to inefficiency, and we see our assumption as a simple way to capture this in the experiment.

[8]A reviewer pointed out that in many real situations payoffs are likely to be private information. We agree that the assumption of complete information can be unrealistic, but leave the study of privately known payoffs for future research.

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distributional properties. The time horizon is finite, but, since there is a multiplicity of Nash equilibria in the stage game, backward induction will not refine the set of equilibria.[9]

3 The Experimental Stage Games

Denote an asset with value x to Player 1 and value y to Player 2 as (x, y). In order to test hypotheses about payoff focality and coordination complexity, we used five stage games:

- Stage Game 1: There is a single asset, $(20, 20)$.
- Stage Game 2: There are two assets, $(4, 4)$ and $(16, 16)$.
- Stage Game 3: There is a single asset, $(32, 8)$.
- Stage Game 4: There are two assets, $(7, 15)$ and $(9, 7)$.
- Stage Game 5: There are two assets, $(8, 20)$ and $(6, 8)$.

As stated earlier, the number and values of the assets are common knowledge. Table 1 below shows the payoff matrix for Stage Game 5. All payoff matrices are in Online Appendix 1. Assets (8,20) and (6,8) are denoted as 1 and 2, respectively. Each player's four pure strategies are: claim neither asset (denoted '0'); claim only Asset 1 ('1'); claim only Asset 2 ('2'), and claim both assets ('12'). In games with a single asset, the strategies are: claim the asset (1) or not (0).

	0	1	2	12
0	$0, 0$	$0, 20$	$0, 8$	$0, 28$
1	$8, 0$	$0, 0$	$8, 8$	$0, 8$
2	$6, 0$	$6, 20$	$0, 0$	$0, 20$
12	$14, 0$	$6, 0$	$8, 0$	$0, 0$

Table 1: Payoff matrix for Stage Game 5: (8,20),(6,8).

[9]More precisely, any individually rational payoff of the bargaining stage game can be sustained in a Nash equilibrium of the repeated bargaining game as the number of periods becomes very large; see Benoit and Krishna (1987).

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Figure 1 shows the feasible Player 1 and 2 *average* payoffs of the five games (i.e., the feasible total payoffs divided by 2400). In the figures these are denoted π_1 and π_2. The average payoffs from playing the same stage game outcome in every period is, of course, equal to the stage game payoffs. These average payoff pairs are shown as black dots in the figures. In what follows, "payoffs" mean average payoffs.

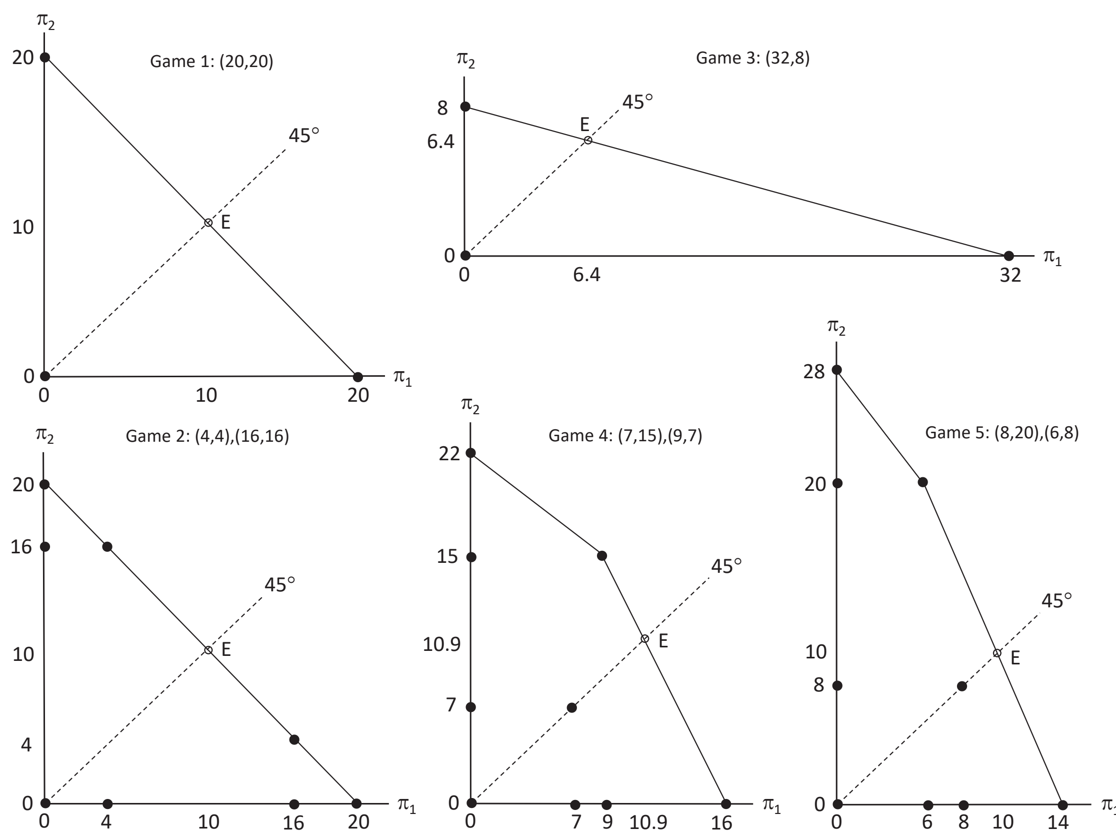

Figure 1: Feasible average payoffs in the five bargaining games. Black dots indicate payoffs that can be obtained from playing the same stage game outcome throughout the bargaining period. The solid line segments are the efficient frontier. The hollow dot is the equal and efficient payoff pair, E.

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Consider any two payoff pairs and some payoff pair on the line segment connecting them. The players can generate this payoff in the game by coordinating on an *intertemporal behavior* where they play each of the stage game outcomes a certain proportion of the time.[10]

An important feature of our bargaining environment is that there are many intertemporal behaviors (in continuous time, an infinite number) that ensure that different stage game outcomes are played certain proportions of time.For example, in Stage Game 1, achieving payoffs $(10, 10)$ requires that each player holds the asset half of the time; this can be achieved by an intertemporal behavior where players swap the asset at certain time intervals, e.g., every 5 seconds; another intertemporal behavior that achieves the same swaps assets every 10, and a third swaps them every 20 seconds, and so on. It is therefore not a priori obvious for how long players should hold the asset before it is swapped.[11] In addition to having to agree on which payoffs of the game they should aim for, the players face a coordination problem in selecting a specific intertemporal behavior achieving those payoffs, and both must be tackled tacitly and in real time.

4 Hypotheses

4.1 Payoff Focality

Our predictions about payoff focality are straightforwardly based on findings from the existing experimental bargaining literature, which has found that there are typically several potentially payoff focal outcomes in a bargaining game (see for example Isoni et al. (2014) and Roth and Murnighan (1982)). The focal candidates include the efficient and equal payoff pair, E; unequal and efficient pairs, especially if they offer larger total earnings than E; we predict that inefficient payoffs are not payoff focal.

Applying these criteria to our five games gives Hypothesis 1 below and the characterization in the second column of Table 2 below. A few remarks are in order. In Game 2 we predict that the payoffs (4,16) and (16,4) are too unequal to be focal relative to (10,10). In Game 4 and 5 we predict that the

[10] This is only approximately true since the number of periods is finite.

[11] In our setting this difficulty is compounded by the fact that there is no obvious 'period' (say hour, day, or week). Strictly speaking, a 'period' in our experiment lasts 1/10 seconds, but this is clearly not behaviorally relevant for the subjects.

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payoffs (7,7) and (8,8) are not payoff focal since they are strictly dominated by the equal and efficient payoff pair, E.

Hypothesis 1. *a. In Games 1 and 2 bargainers achieve payoffs* $E = (10, 10)$.
b. In Game 3 bargaining pairs achieve a payoff pair on the efficient frontier equal to, or to the right of, $E = (6.4, 6.4)$.
c. In Game 4 subjects achieve payoffs $E = (10.9, 10.9)$, *or* $(9, 15)$, *or any payoff pair on the efficient frontier between them. No bargaining pairs settle on payoffs (7,7), since they are strictly dominated by* $E = (10.9, 10.9)$.
d. In Game 5, subjects achieve payoffs $E = (10, 10)$, *or* $(6, 20)$, *or any payoff pair on the efficient frontier between them. No bargaining pairs settle on payoffs* $(8, 8)$, *since they are strictly dominated by* $E = (10, 10)$.

4.2 Coordination Complexity

Consider some feasible payoff pair, $\pi = (x, y)$. We think of the *coordination complexity* of π as measuring how difficult it is for players to coordinate on an intertemporal behavior that generates payoffs π. We distinguish between a *time-constant* intertemporal behavior, where the players play the same stage game outcome throughout the bargaining period, and a *time-varying* behavior, where they select different stage game outcomes different proportions of time. It is intuitively more difficult to coordinate on a time-varying than a time-constant behavior, since the former requires that each player holds the assets a certain proportion of time. Recall also, as pointed out in Section 3, that there are many intertemporal behaviors that achieve these aggregate time proportions.[12] So we predict that it is more difficult for players to achieve a given payoff pair π if it requires a time-varying than a time-constant behavior.

The last column in Table 2 describes the intertemporal behaviors that are required for generating the payoff focal outcomes described in the previous section.[13]

We now develop some hypotheses for how payoff focality and coordination complexity interact. Our first prediction is that, *ceteris paribus, higher coordination complexity is detrimental for earnings*. Games 1 and 2 have

[12] As mentioned in the Introduction, the players thus face a coordination problem in selecting a specific time varying behavior from the set of all the time varying behaviours that achieve the required aggregate time proportions.

[13] These are straightforward to compute—see Online Appendix 4.

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Game	Predicted focal payoffs	Intertemporal behaviors generating focal payoffs
Game 1: (20,20)	$E = (10, 10)$.	Time varying: Each player holds the asset half the time.
Game 2: (4,4),(16,16)	$E = (10, 10)$.	Time varying: i) Each player holds both assets half of the time. ii) Half of the time one player holds A1 and the other player holds A2, and the other half the opposite happens. iii) Player 1 always holds A1 and 5/8 (3/8) of the time Player 1 (2) holds A2. iv) Player 1 always holds A2 and 3/8 (5/8) of the time Player 1 (2) holds A1. v) Players coordinate on holding the assets such that each of the payoffs (0,20), (4,16), (16,4), and (20,0) occur a proportion 1/4 of the time. vi) The players coordinate on any three of the four stage game payoffs with time proportions giving payoffs (10,10).
Game 3: (32,8)	$E = (6.4, 6.4)$ and any payoff (π_1, π_2) on the efficient frontier below E.	(6.4,6.4): Time varying. Player 1 (2) holds the asset a proportion 1/5 (4/5) of the time. (π_1, π_2): Time varying. Player 1 (2) holds the asset a proportion $\pi_1/32$ $((32 - \pi_1)/32)$ of the time.
Game 4: (7,15),(9,7)	(9,15), $E = (10.9, 10.9)$, and any payoff (π_1, π_2) on efficient frontier connecting (9,15) and E.	(9,15): Time constant: Player 1 holds A2 and Player 2 holds A1 throughout the period. $E = (10.9, 10, 9)$: Time varying. Player 1 always holds A2; A1 is held by Player 1 (2) a proportion 3/11 (8/11) of the time. (π_1, π_2): Time varying. Player 1 always holds asset A2, and A1 is held by Player 1 a proportion $(\pi_1 - 9)/7$ of the time, and Player 2 holds it the remaining time.
Game 5: (8,20),(6,8)	(6,20), $E = (10, 10)$, and any payoff (π_1, π_2) on efficient frontier connecting (6,20) and E.	(6,20): Time constant. Player 1 holds A2 and Player 2 holds A1 throughout the period. $E = (10, 10)$: Time varying. Player 1 always holds A2; A1 is held by each player half the time. (π_1, π_2): Time varying. Player 1 always holds A2, and A1 is held by Player 1 a proportion $(\pi_1 - 6)/8$ of the time, and Player 2 holds it the remaining time.

Table 2: Predicted payoff focal outcomes and intertemporal behaviors generating the focal payoffs in each of the five games. Note: In Games 3, 4, and 5, A1 = Asset 1 and A2 = Asset 2.

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the same feasible payoffs and are predicted to have the same unique focal payoff pair, $E = (10, 10)$, but the coordination complexity of E (in fact of any payoff on the efficient frontier) is higher in Game 2 than in 1, since there are more time-varying behaviors generating E in Game 2 than in 1 (cf. table 2).

Hypothesis 2. *Player 1 and 2's earnings in Game 2 are below those in Game 1, due to higher coordination failure in Game 2 than in Game 1.*

Suppose now that achieving an equal and efficient outcome E requires a time-varying behavior, and suppose also there is a time-constant behavior that gives equal but inefficient payoffs (cf Games 4 and 5). Our third hypothesis is that *bargainers settle on a time constant behavior giving equal but inefficient payoffs instead of the time varying equal and efficient behavior, but only if the equal stage game payoffs are not dominated by other stage game payoffs*. In other words, the bargainers are willing to abandon an equal and efficient outcome of the overall game if this requires a complex coordination behavior – but when considering simpler coordination schemes they are unwilling to sacrifice efficiency for equality. In this sense efficiency has priority over equality among the time constant behaviors.

Hypothesis 3. *a. In Game 5 significantly more bargaining pairs settle on a time-constant behavior giving payoffs $(8, 8)$ than on a time-varying behavior giving payoffs $E = (10, 10)$. b. In Game 4 no bargainers settle on the time-constant behavior giving payoffs (7,7) since it is strictly dominated by the time-constant behavior giving payoffs (9,15).*

We also predict that *complexity differences between payoffs along the efficient frontier affect how bargainers trade off equality and surplus maximization concerns*. Observe that along the efficient frontier in Game 3 the equal payoff, E, is as complex to settle on as unequal payoffs, while in Games 4 and 5 payoff E is more complex than the alternative payoffs, (9,15) and (6,20).

Hypothesis 4. *Significantly fewer bargaining pairs generate equal payoffs E in Games 4 and 5 than in Game 3.*

Our last hypothesis is that *if there are complexity differences* within *the set of time-varying behaviors, then bargainers settle on the simpler ones even if it leads to a loss of efficiency*. In Game 5 players can achieve any payoff on the line connecting (8,8) and (6,20) by coordinating on a time-varying behavior

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where they swap the assets and hold each a certain proportion of time; this leads to an inefficient outcome, but it is arguably simpler than the time-varying behavior required for getting on the efficient frontier, namely (cf Table 2) that Player 1 half of the time holds both assets and the (8,20) asset is held by each half the time.

Hypothesis 5. *In Game 5 significantly more bargainers tend to settle on an inefficient time-varying behavior generating payoffs on the line connecting (8,8) and (6,20) than on an efficient time-varying behavior generating payoffs on the frontier between E and (6,20).*

5 Experimental Design and Procedures

The experiment was conducted at the Centre for Behavioural and Experimental Social Science (CBESS) at University of East Anglia (Norwich, UK). 156 subjects took part. The subjects were undergraduates and postgraduates from the sciences and humanities. There were eight sessions. Sessions lasted between 50 and 60 minutes. Average earnings (including the £3 participation fee) were £12.49. Recruitment was done using ORSEE (Greiner (2015)). The experiment was programmed and conducted with the software z-Tree (Fischbacher (2007)).

Upon arrival, subjects were seated at desks. Each subject received a hard copy of the instructions (see Online Appendix 1). These were read out by the experimenter. The instructions explained that each subject would play five bargaining games (called "scenarios" in the instructions), each against a randomly selected co-participant.[14] Each scenario lasted four minutes (240 seconds). Participants were explained that they would be referred to as either the Red or the Blue player, and that they would keep this role in all five scenarios. Participants did not know the five scenarios before playing them.

Participants were then introduced to the decision interface, using a live step-by-step tutorial explaining all features of the screen. The screen showed the asset(s) (referred to as "objects"), visually represented by cir-

[14]In each session all participants encountered the games in the same order. We used two orders, 2, 3, 1, 5, 4 and 4, 5, 1, 3, 2. We considered the data for each game order and found no systematic order effects (details are available from the authors upon request), and therefore pooled the data.

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cles (see the screenshot in Figure 5 below).[15] Inside each circle was written the value of the asset to each player, in terms of points. The first number always referred to the Blue player's value, and the second number was the Red player's value. The total number of earned points would be converted into pounds at the end of the experiment.

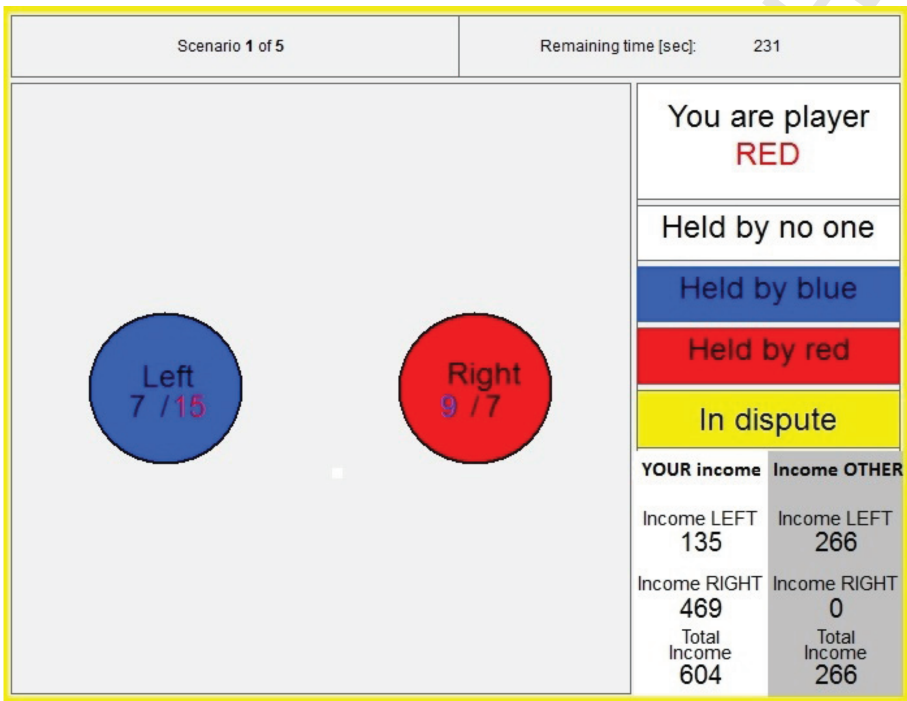

Figure 2: Screenshot. Objects were colored, as explained in the main text. The field "Held by no one" ("Held by Blue") ["held by Red"] [["in dispute"]] is colored white (blue) [red] [[yellow]].

In each scenario a subject could click with his or her mouse on an object. They could click on as many objects as they liked, and as often as they liked, during the four minutes.

Subjects were then explained the rules:

- At the beginning of each scenario, all objects are white. This indicates that no one holds any objects.

[15]Similar representations have been used in other experiments; see Isoni et al. (2013), Isoni et al. (2014), and Mehta et al. (1994).

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- If the Red (Blue) player clicks on a white object, then the Red (Blue) player holds the object and gets its value, and the object then gets the color of the player who clicked on it (blue or red).
- If an object is already held by one of the players (such that it has a red or blue color), and the other player then clicks on it, the object is in dispute. This means that no player holds the object, so no one gets its value. To show this, the object turns yellow.
- If one player holds an object (so it has that player's color), and he or she then clicks on it again, then that player gives up the object. Then no one holds it, so the object gets a white color.
- If an object is in dispute (yellow color) and a player clicks on it, then the other player holds it, so it gets the other player's color.

The point-and-click interface allows participants to easily make and change their decisions. As already mentioned, participants only needed to click when they wanted to *change* their existing claims—the computer maintained their claim on their behalf until they made a new claim using their mouse.

Next, subjects were explained the rules governing how they earned points: as long as an object was in a subject's possession, he or she would get its value per unit of time. More precisely, the income from holding any object was recalculated every 10th of a second and added up. The total income is the sum of the total income from each of the objects.

Subjects were provided with real-time earnings information on the screen. In the lower right corner, they were shown a table with two columns. The first column showed the subjects' total point income from each object, and the total income. The second column showed the co-partipant's income. These numbers were updated every tenth of a second.

At the end of the session, the computer randomly selected one of the five scenarios. The total number of earned points in this scenario was converted into pounds using the exchange rate: 100 points = 5.3 pence (= £0.053). In other words, £1 = 1887 points. While the calculation of payments was done without any rounding, the final payment was rounded up to the nearest full 5 pence, in order to facilitate the payment procedure.

After the instructions had been read out, a short on-screen tutorial was shown on participants' screens, showing subjects how to use the interface. Any questions were answered, and the experiment began.

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6 Results

6.1 Overview

For each bargaining pair, the *state* of bargaining at time t is given by the *strategy profile*, that is, each subject's chosen stage game strategy at that time. From now on "strategy " always means pure stage game strategy.

Table 3 shows the proportion of time each strategy profile was observed in each of the five games. The assets are denoted 1 and 2 (in Games 1 and 3 the single asset is denoted 1). A strategy profile is denoted (i, j), where in games with two assets $i, j = 0, 1, 2, 12$ denote the four strategies of claiming neither asset, claiming only Asset 1, claiming only Asset 2, and claiming both assets. For example, strategy profile (2,12) is where Player 1 demands only Asset 2 and Player 2 demands both assets. In Games 1 and 3, the two strategies are denoted 0 and 1.

Table 4 shows data on various outcome measures. The first row gives subjects' average earnings in each player role. Total Payoff Efficiency (TPE) measures the extent to which subjects maximized total earnings.[16] Closeness to the Efficient Frontier (CEF) is a measure of how close a payoff vector is to the efficient frontier.[17] In Games 1 and 2, TPE = CEF.[18] Earnings Inequality is the average within-pair difference in earnings.[19] The row Asset Holding Durations states, for each asset, the proportion of time the asset was held by Player 1 and 2, respectively. For example, in Game 2 the (16,16) asset was held by Player 1 (2) 33.56% (30.22%) of the time. There are two sources of inefficiency in our bargaining environment, both or neither

[16]Consider one of the five games and suppose average payoffs are $\pi = (x, y)$, where x (y) is Player 1's (2's) average payoff. Total Payoff Efficiency of π is the ratio of total earnings to the maximum possible total earnings, i.e., $TPE = (x + y)/M$, where $M = 20, 20, 32, 26, 26$ in the five games.

[17]Consider the payoff pair $\pi = (x, y)$, where x (y) are Player 1's (2's) earnings. Assuming that $x > 0$ and $y > 0$, consider the vector π' from the origin, obtained by extending π until it reaches the efficient frontier. Denote by $\overline{\pi}$ the length of the vector π. We then define the Closeness to the Efficient Frontier of π as $\alpha = \overline{\pi}/\overline{\pi'}$. We have $0 < \alpha \leq 1$. If $\alpha = 1$, π is on the efficient frontier. If $\alpha < 1$, the subjects only achieved a fraction α of full efficiency. If $\pi = (0, 0)$, we set $\alpha = 0$.

[18] Efficiency requires that all assets are held by someone, and since in Game 1 and 2 all assets have the same value to each player, any such state also maximizes total earnings.

[19]We compute for each bargaining pair the absolute difference between the subjects' earnings, and then compute the average across all bargaining pairs.

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Strategy Profile	Game 1: (20,20)	Game 2: (16,16),(4,4)	Game 3: (32,8)	Game 4: (7,15),(9,7)	Game 5: (8,20),(6,8)
$(0,0)$	1.73	0.15	1.03	0.04	0.02
$(0,1)$	36.44	0.59	49.77	0.50	0.68
$(0,2)$	–	0.98	–	0.25	0.09
$(0,12)$	–	2.77	–	1.13	0.73
$(1,0)$	37.47	0.27	21.90	0.27	0.50
$(1,1)$	23.92	0.21	26.83	0.48	0.96
$(1,2)$	–	24.17	–	7.55	35.43
$(1,12)$	–	2.29	–	1.82	3.49
$(2,0)$	–	0.54	–	0.99	0.25
$(2,1)$	–	26.33	–	64.19	30.21
$(2,2)$	–	1.23	–	0.42	0.13
$(2,12)$	–	5.65	–	1.45	1.15
$(12,0)$	–	3.85	–	3.61	5.22
$(12,1)$	–	2.83	–	4.11	5.64
$(12,2)$	–	6.99	–	1.70	1.83
$(12,12)$	–	20.60	–	10.84	13.13

Table 3: The percentage of time each strategy profile was observed in each of the five bargaining games. The numbers are averages across all bargaining pairs.

subject claiming an asset. The row Asset Dispute Rates gives the percentage of time where each asset was claimed by both subjects. Finally, the row Asset Idleness Rates gives the percentage of time where neither subject claimed the asset.

Figures 3 – 7 show scatterplots of the payoffs in each of the five games (each dot is the payoffs obtained by a pair of subjects). Due to the chosen scaling, only a part of the efficient frontier is shown.

The data just described are averages across bargaining pairs. The reader may however be interested in the the dynamics of individual bargaining pairs. Online Appendix 6 contains a description of the bargaining dynamics of a broadly representative set of bargaining pairs.

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	Game 1: (20,20)	Game 2: (4,4),(16,16)	Game 3: (32,8)	Game 4: (7,15),(9,7)	Game 5: (8,20),(6,8)
Player 1 and 2 average earnings	7.50,7.29	6.78,6.25	7.01,3.98	7.40,10.75	5.93,9.75
Total Payoff Efficiency (TPE) (%)	73.9	65.2	34.3	75.6	56.0
Closeness to Efficient Frontier (CEF) (%)	73.9	65.2	72.4	79.2	70.7
Earnings Inequality	0.63	1.52	3.08	3.86	4.31
Asset Holding Durations (%)	37.47,36.44	(4,4): 35.29,35.34 (16,16): 33.56,30.22	21.90, 49.77	(7,15): 13.13,67.27 (9,7): 72.90,10.76	(8,20): 42.99,32.77 (6,8): 41.32, 39.73
Asset Dispute Rates (%)	23.92	(4,4): 25.93 (16,16): 34.47	26.83	(7,15): 17.25 (9,7): 14.40	(8,20): 23.22 (6,8): 16.25
Asset Idleness rates (%)	1.73	(4,4): 2.91 (16,16): 1.22	1.03	(7,15): 1.69 (9,7): 1.28	(8,20): 0.48 (6,8): 2.16

Table 4: Aggregate data. All data are means, computed across all bargaining pairs. Note: In Games 1 and 2, TPE = CEF, by definition (see main text).

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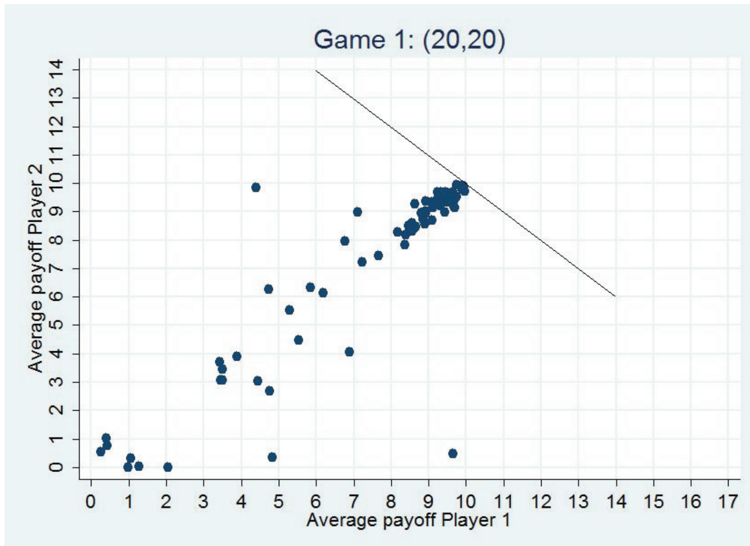

Figure 3: Scatter plot of average payoffs pairs in Game 1.

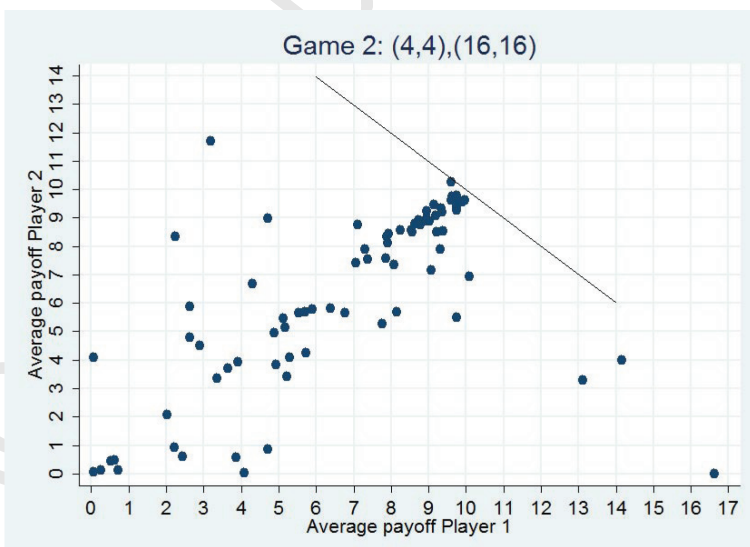

Figure 4: Scatter plot of average payoffs pairs in Game 2.

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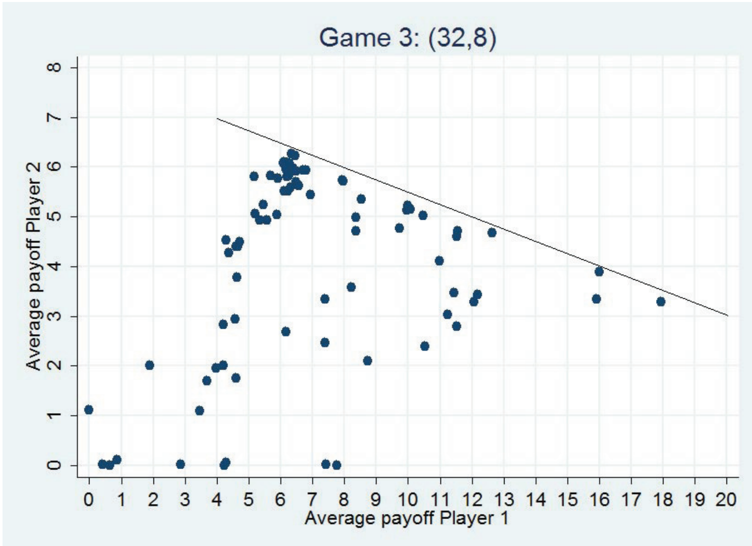

Figure 5: Scatter plot of average payoffs pairs in Game 3.

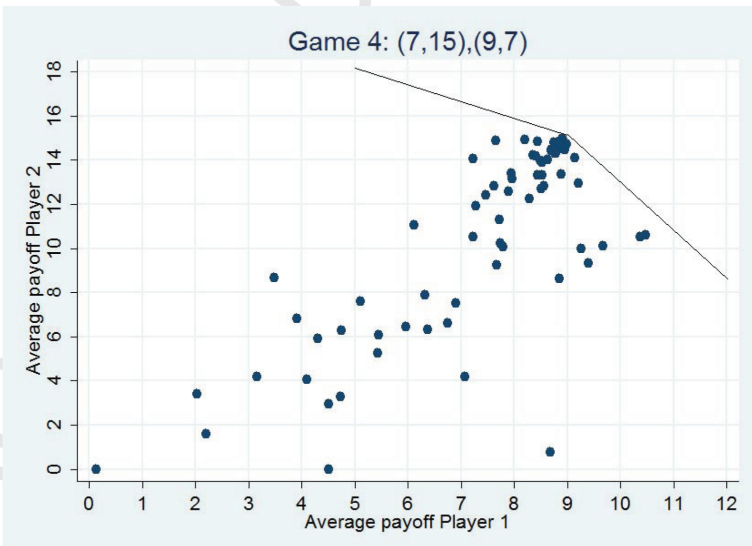

Figure 6: Scatter plot of average payoffs pairs in Game 4.

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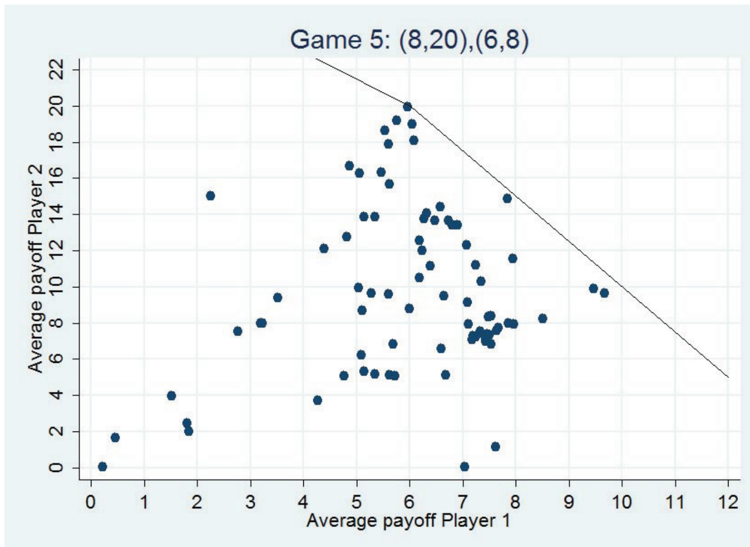

Figure 7: Scatter plot of average payoffs pairs in Game 5.

6.2 Assessing the Hypotheses

Games 1 and 2 In Game 1 Player 1 and 2's payoffs are close and not statistically significantly different (Wilcoxon signed-rank test for matched pairs, $p = 0.288$; using session averages give the same conclusion ($p = 0.4008$)). Within each bargaining pair the subjects tend to hold the asset the same amount of time (between 36 and 38% of the time). The object is in dispute for almost 24% of the time; it is idle less than 2% of the time. Inefficiency is thus overwhelmingly due to dispute and not to assets lying idle; this is the case for all games.

Average Player 1 and 2 payoffs are also similar in Game 2 (and not significantly different, Wilcoxon signed-rank test, $p = 0.14$; at the session level, $p = 0.1614$). As can be clearly seen in Figure 4, a large majority of bargaining pairs establish an alternation between stage game payoff pairs (4,16) and (16,4) that give approximately equal payoffs. There is however more dispersion than in Game 1, and outcomes are generally less efficient, due to each asset being in more dispute in Game 2 than 1. Total earnings and TPE=CEF in Game 1 are significantly higher than in Game 2 (Wilcoxon-Mann-Whitney test, two-sided, $p = 0.01$; using session aver-

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ages yields $p = 0.0157$). Also, with the exception of two or three bargaining pairs, no one settles on a time constant behavior giving payoffs close to (4,16) or (16,4).

Finding 1. *In Games 1 and 2 most bargaining pairs generate approximately equal overall payoffs, confirming the payoff focality of* $(10, 10)$*, but dispute is significant in both games. Moreover, there is significantly more dispute in Game 2 than in Game 1. Thus earnings and Total Payoff Efficiency in Game 2 are lower than in Game 1. These findings reject Hypothesis 1a in favor of Hypothesis 2.*

Game 3 We next consider Game 3. Figure 5 shows that a significant proportion of bargaining pairs cluster on an equal outcome on the 45-degree line, and that many get close to the equal and efficient outcome, $E = (6.4, 6.4)$, where Player 1 holds the asset $1/5$ and Player 2 holds it $4/5$ of the time. Twenty bargaining pairs (about 25%) satisfy a criterion that the time proportions with which each player holds the asset differ by no more than .1 from those that generate payoffs E. The clustering of outcomes near E can be more clearly seen in the scatterplot in Figure 1 in Online Appendix 3, which for each bargaining pair shows the proportion of time the pair selected strategy profile $(1, 0)$ and on profile $(0, 1)$.

There is, however, a significant dispersion in payoffs. Many bargaining pairs settle on payoffs on or close to other parts of the efficient frontier, where there is significant inequality in favor of Player 1, and where total earnings are higher. Player 1 earns on average more than 75% more than Player 2 (this difference is significant, Wilcoxon signed-rank test, two-sided, $p < 0.0001$; at the session level, $p = 0.0117$). On the other hand, Player 2 holds the asset more than twice as often as Player 1. We summarize these results below.

Finding 2. *In Game 3 a significant proportion of bargaining pairs generate equal and efficient payoffs E, but many pairs settle on outcomes on or close to the efficient frontier that trade off inequality and total surplus maximization. These findings support the distributional, but not the efficiency, part of Hypothesis 1b.*

Game 4 Figure 6 shows that very few bargainers get close to generating payoffs E. Moreover, the strategy profile $(1, 2)$ that generates equal and

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inefficient payoffs $(7,7)$ is on average observed less than 8% of the time.[20] Instead the strategy profile (2,1) is observed almost two thirds of the time on average. The percentage of bargaining pairs selecting strategy profile $(2,1)$ at least 60, 70, 80, or 90 percent of the time equal 62, 55, 50, and 36 percent, respectively.

Game 5 Table 3 shows that bargaining pairs select each of strategy profiles $(1,2)$ and $(2,1)$ (giving payoffs $(8,8)$ and $(6,20)$, respectively) about a third of the time, and only about 5% of the time do they select profile $(12,0)$, where Player 1 holds both assets, which is needed for generating payoffs E. These numbers are however averages across all bargaining pairs, so they may mask heterogeneity at the level of bargaining pairs. For example, it is not clear if a bargaining pair tends to select only strategy profile (1,2) or only (2,1), or if the typical bargaining pair tends to select both profiles during the bargaining period. A closer look at the data (see Table 5 in Online Appendix 5) reveals that 21 bargaining pairs (about 25%) select strategy profile (1,2) at least 60% of the time, and 15 pairs (19%) select that profile 70% of the time or more. Thus a significant proportion of bargaining pairs have a high degree of coordination on the payoff pair (8,8), even though this is strictly dominated by $E = (10,10)$. There is also significant coordination on the strategy profile (2,1), giving payoffs (6,20): 13 bargaining pairs (16%) select this strategy profile at least 60% of the time, and 10 pairs (13%) select it 70% of the time or more.

Finding 3. *In Game 5 a significant proportion of bargainers generate a time-constant behavior giving either payoffs $(8,8)$ or $(6,20)$, while in Game 4 very few pairs generate payoffs (7,7). This rejects Part d of Hypothesis 1 and supports Hypothesis 3.*

We next consider the payoffs E in Games 4 and 5. Table 3 shows that in Game 4 very few bargaining pairs generate payoffs equal or close to $E = (10.9, 10.9)$. A more detailed look at the data reveals that only three bargaining pairs achieve payoffs to the northeast of (9,9).[21] Similarly, in Game 5 very few pairs achieve payoffs $E = (10,10)$. First, strategy profile

[20]The percentage of bargaining pairs that generate payoffs $(7,7)$ at least 50% or 60% of time equal 6% and less than 1%, respectively.

[21]One bargaining pair is able to get remarkably close to $E = (10,9,10.9)$, achieving payoffs (10.37,10.50). See Online Appendix 6 (Figure 25).

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(12,0) is observed very infrequently. Only 5 bargaining pairs (7%) settle on strategy profile $(12, 0)$ 30% or more of the time. 49 bargaining pairs have a zero coordination rate on $(12, 0)$, and among the remaining 29 pairs the vast majority generate $(12, 0)$ less than 5% of the time. See the histogram in Figure 2 in Online Appendix 3. Table 5 in Online Appendix 5 shows that only two out of the 78 bargaining pairs get close to E; see also the scatterplot in Figure 3 in Online Appendix 3.

Finding 4. *In both Games 4 and 5 very few bargaining pairs achieve payoffs close to E. This, together with Finding 2, supports Hypothesis 4.*

We finally consider Hypothesis 5. It is clear from Figure 7 that a significant proportion of bargaining pairs achieve payoffs close to the line connecting $(8, 8)$ and $(6, 20)$. Payoffs on this line require a time-varying behavior where subjects swap the assets, that is, switch between strategy profiles $(1, 2)$ and $(2, 1)$. Although strictly dominated, this time-varying behavior is arguably simpler than the one required for generating payoffs E. Table 5 in Online Appendix 5 shows that 20 pairs (about 25%) generate each of these strategy profiles 20% or more of the time; 12 bargaining pairs (15%) generate each strategy profile 30% or more of the time.

Finding 5. *In Game 5 a significant proportion of bargaining pairs achieve a high degree of coordination on a time-varying behavior that gives strictly dominated payoffs on the line connecting payoffs* $(8, 8)$ *and* $(6, 20)$*. This supports Hypothesis 5.*

7 Conclusion

We experimentally study a novel real time tacit non-cooperative bargaining environment, with the aim of capturing and illuminating how the focality of payoff opportunities, and the complexity of coordinating on them interact. We document three empirical regularities. First, ceteris paribus higher coordination complexity is detrimental. Second, bargainers trade off payoff focality and coordination complexity – if the equal outcome is relatively complex, more bargainers settle on on an unequal outcome. Third, bargainers settle on an inefficient equal outcome if is simpler than an equal and efficient outcome, but only if the former is not dominated by other unequal and as simple outcomes. These findings demonstrate that

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in order to predict behavior in real world bargaining situations like the ones studied here we need to take not only the focality of payoffs but also their coordination complexity into account.

We believe there is scope for much future research. First, one should relax the assumption that payoffs are commonly known. Intuitively, private payoff information make considerations based on payoff complexity much weaker relative to coordination complexity. Second, it is relevant to investigate if complexity matters as much much if decision makers can communicate via cheap talk while making bargaining moves. Third, it seems important to understand why bargainers tend not to settle on complex coordination schemes. One hypothesis is that subjects are unable to compute or even conceptualize complicated time-varying behaviors. Another possibility is that they do understand what intertemporal behavior is required, but believe that others do not, and therefore find the required complex behavior too risky. A third conjecture is that the tacit interaction makes people pessimistic that they can generate a complex intertemporal behavior, and hence they avoid it. Of course, all these and other factors may play a role; our experiment was not designed to distinguish between them, but future research can address this issue.

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