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

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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 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 game played at every time instant (the "stage game") possesses 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)).

A theoretical analysis of such a bargaining environment based on the Nash equilibrium concept is unable to make sharp predictions, due to the multiplicity of equilibria in the stage game, and because (as in most repeated games; see Mailath and Samuelson (2006)) there is a large number of equilibria of the overall bargaining game, and, as we shall se, these possess different efficiency and distributional characteristics. This absence of strong theoretical predictions, coupled with the lack of high quality observational data, makes it relevant to conduct an exploratory bargaining experiment, so we can form an expectation about what behavior might be observed in a real-world setting.

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 decide when and for how long to use a commonly owned outdoor area, playground,

[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.

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

Two armies fighting over land Each army decides in real time which areas to occupy and receives the corresponding flow payoffs from the land it is currently occupying. Each side would like to get as much land as possible, but also to avoid a severe conflict.

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.

To an outside observer these situations may not resemble negotiation situations—no discussion takes place around a negotiation table, there is no exchange of offers and counteroffers, and no contracts are signed. The settings we consider nonetheless have the core features of bargaining: each side can take actions that raise his payoff if they make the other side "retreat" and accept lower earnings, and there are many ways the players can coordinate their behavior over time. The bargaining moves are *real*: they are physical actions (not just verbal proposals uttered around the bargaining table), and therefore immediately affect players' earnings. Of course, various degrees of dispute can arise, and the questions are i) if the players manage to coordinate their behavior in a way that avoids such inefficiency, and ii) what form such coordination will take—for example, will players find a way to take turns in using individual assets (say a fishing spot), or will they settle on a fixed time-invariant division of the assets?

The assumption that interaction is tacit is obviously important. While it may not be descriptively correct for some bargaining environments, it seems a good approximation for those described above. Tacit interaction can arise due to communication being illegal (as in a market where a firm faces very large penalities for discussing market conditions with other firms), too expensive, impractical or impossible, or because players prefer not to communicate (two neighbors, or countries at war). This can be contrasted with "explicit bargaining" (Schelling (1960)), where players can communicate via cheap talk before or while making bargaining moves.

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)).[2] We expected that focal properties, such as payoff equality, payoff efficiency, and total payoff maximization would influence behavior.[3] We use the term *payoff focality* to refer to these payoff-based sources of focality.

Second, since players earn and cumulate their payoffs over time, they need to coordinate on an intertemporal behavior that achieves the focal payoffs of the overall game. We expected that the degree of difficulty of achieving such coordination, which we refer to as *coordination complexity*, will be behaviorally relevant.

We also conjectured that there would be a trade off between payoff focality and coordination complexity. Suppose a payoff pair π is more payoff focal than another, π'. The lower the coordination complexity of π' relative to π, the more likely bargainers are to settle on π' instead of π. This can happen for several reasons. The bargainers may, due to cognitive constraints (see, for example, Ho and Weigelt (1996) and Gigerenzer et al. (1999)), systematically fail to understand and consider intertemporal behaviors with high coordination complexity; if these are required in order to generate an otherwise payoff focal outcome, the latter will not be behaviorally relevant. Subjects may also, due to a desire to conserve cognitive effort, have a preference not only for high payoffs but also for simple intertemporal behaviors that reduce the risk of coordination failure.

Of course, many aspects other than payoff focality and coordination complexity can matter. For example, bargainers may be competitive or spiteful and deliberately seek conflict. We do not deny the potential role played by such and other considerations. Nevertheless, we believe that thinking about behavior in terms of payoff focality and coordination complexity, and the way they interact, provides an intuitive and quite simple

[2]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 van Huyck et al. (1992), Gächter and Riedl (2005), Galeotti et al. (2015), 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), Isoni et al. (2014), and Schelling (1960).

[3]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.

framework for generating expectations about behavior in any specific bargaining environment. Perhaps more importantly, as we explain in the next paragraph, they help us to organize and understand the data.

We collect data for different bargaining games that differ in payoff focality and coordination complexity. Our findings can be summarized as follows. The data are consistent with the hypothesized role played by both payoff focality and coordination complexity, and, the data can be organized and understood in terms of the trade off that was described above. More precisely, bargainers systematically settle on inefficient outcomes if the intertemporal behavior required to implement efficient payoffs is relatively complex. Furthermore, if it is no more complicated to coordinate on equal than on unequal payoffs, then most bargainers prefer the former. If, however, equal payoff outcomes have higher coordination complexity than other outcomes, then bargainers tend to settle on the latter, even when these are strictly dominated.

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 agreements alone, since these also depend on coordination complexity. Thus, in our bargaining environments, an analyst seeking to predict and explain behavior must consider not only the feasible payoffs but also their complexity.

We are, to the best of our knowledge, the first to report experimental data for real time bargaining situations[4], but there are connections to several other research areas. 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 has considered bargaining situations.[5]

[4]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).

[5]In Camerer et al. (2015) and Galeotti et al. (2015) players make proposals in real time,

Second, we contribute to the experimental bargaining literature by considering an environment where players make moves and earn payoffs in real time, and there is no third party who can prevent players from claiming parts of the surplus whenever they wish.[6]

Our paper can also be related to the theoretical literature on boundedly rational behavior in repeated games (see Abreu and Rubinstein (1988), Binmore et al. (1998), Chatterjee and Sabourian (2000), and Kalai (1990)). This literature assumes that players choose simplified strategies (represented by finite state automata), and payoffs depend both on repeated game payoffs and the complexity cost of the machine. As far as we know, there are no experiments in this area. Our experiment implements an environment that differs from these models in that subjects do not submit entire repeated game strategies at the outset of the session but can change their submitted stage game strategy in real time as often as they wish.

There are also several important differences between the environment studied in the current paper and those considered in the experimental literature on cooperative behavior in repeated games (see, for example, Bhaskar (2000), Bjedov et al. (2015), Bornstein et al. (1997), Cason et al. (2013), Evans et al. (2013), Kaplan and Ruffle (2012), Kuzmics and Rogers (2012), 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 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 strategies. This creates a strategic environment with qualitatively new features. More precisely, the time proportions with which different stage game outcomes need to be coor-

but earnings are not cumulated over time, and an agreement is assumed to be binding and terminates interaction.

[6]The existing studies (see Camerer (2003) and Roth (1995) for reviews) are based on unstructured bargaining situations (see for example Camerer et al. (2015), Feltovich and Swierzbinski (2011), Galeotti et al. (2015), Gächter and Riedl (2005), Herreiner and Puppe (2010), Isoni et al. (2014), Karagözoglu and Riedl (2015), Roth (1995), and Roth and Murnighan (1982)), or alternating offers bargaining games (see Muthoo (1999), Roth (1995), and Rubinstein (1982)). These models assume there is an 'enforcer' who can implement and enforce an agreement.

dinated on in order to generate equal and efficient payoffs of the overall game differ from one-half. Furthermore, and crucially, 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 repeated game; nevertheless, as we shall see, the former payoff pair may be so much simpler to coordinate on that many bargainers settle on the former, strictly dominated, behavior. This evidence on the role played by coordination complexity, has, as far as we know, no counterparts in the existing literature.

The rest of the paper is organized as follows. Section 2 describes the bargaining stage games and the real-time bargaining game. Section 3 formulates some hypotheses. We explain the experimental design and logistics in Section 4. The data are described and analysed in Section 5. Section 6 concludes. The Appendix contains instructions, screenshots, and additional data.

2 The Bargaining Environment

2.1 The Bargaining Stage Games

There are one or two indivisible assets. 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 can claim 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 asset, no one gets it.[7] We then say the asset is in *dispute*. As we explain below, in the experiment the assets were shown on subjects' screens as disc-like objects, and a subject claimed them by clicking on them with his or her mouse.

A player who holds an asset receives the value of the asset. Denote an asset with value x to Player 1 and value y to Player 2 as (x, y).[8]

[7] Our assumption that conflict over an asset completely destroys its value is extreme. In practice there may still be some sharing of the asset, as in our motivating examples (two fishermen occupying the same fishing spot may still catch some fish). The important thing, however, is that conflict over an asset leads to inefficiency (there will be some skirmishes between the fishing crews as they seek to share the area between them, which delays the fishing or perhaps even leads to some physical and costly confrontation), and we see our assumption as a simple way to capture this in the experiment.

[8] We thus assume that the value of an asset to a player does not depend on which other

We collected data using five different 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 $(6, 8)$.

The number and values of the assets are common knowledge.

We would of course not claim that these simple stage games capture any specific bargaining situation. Their purpose is rather to qualitatively capture the payoff structures of real world bargaining situations, and enable us to assess hypotheses about payoff focality and coordination complexity that we develop below.[9]

Tables 1 below shows the payoff matrix for Game 5. All payoff matrices are in Online Appendix 1. Asset (8,20) [(6,8)] is denoted 1 [2]. 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).

All five stage games have several Nash equilibria. Any division of the assets is a Nash equilibrium, as is the outcome where one player claims

assets the player him or herself, or the other player, holds. In other words, there are no payoff complementarities and no externalities.

[9]We can interpret our stage game as a stylized representation of situations such as those described in the Introduction. An asset can represent a fishing spot, a market, an area of land, or a parking space, where the value of the asset represents the payoff to a player who can get sole access to it. Game 1 can be interpreted as a situation where there is a single resource (say one parking space, fishing spot, or sales district), worth the same to each player (neighbor, fisherman, salesperson). In order to earn money efficiently, the players must coordinate their behavior such that they do not both try to access the resource at the same time. Game 2 captures a situation where there are two resources, one being more valuable to both players (say, a parking space close by and another farther down the road). Game 3 has a single asset, as Game 1, but the resource is now valued differently by the players. Games 4 captures a situation with, say, two fishing spots, each of which is preferred by a different fisherman, but if each fisherman claims his preferred spot then there will be inequality in earnings. Finally, Game 5 captures a situation where there is an equal and efficient asset division (giving (8,8)) and another unequal but total surplus maximizing division (giving (6,20)).

one asset and the other asset is in dispute, and the outcome where each player claims all assets. There are also many mixed equilibria. 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 the equilibrium where each player claims all assets and equilibrium payoffs are zero.

	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).

2.2 The Repeated Bargaining Game

The bargaining period has a fixed and commonly known length, T, and is divided into a large number of 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. In the experiment, T equals 240 seconds, and the computer takes a reading every $1/10$ of a second. There are thus 2400 periods. Subjects did not have to choose a strategy every period (this would clearly be imposible given the very short period length); they only had to submit a new strategy when they wished to *change* their existing strategy, and they could do this as often as they wished.

From a theoretical point of view 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 distributional properties. For example, there are equilibria of the repeated game where players in each period coordinate on some fixed division of the assets, sustained by punishment strategies where each player in case of a deviation demands all assets. It is also an equilibrium that each player in each period demands all assets, and it is an equilibrium that players play different stage game equilibria in different periods; these equilibria are sustained by the same punishment strategies as just described. 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. 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).

2.3 Feasible Payoffs and Intertemporal Behaviors

The 240-seconds bargaining period is divided into 2400 periods, in each of which the computer records the current earnings and add these to the existing earnings. Figure 1 shows the feasible Player 1 and 2 *average payoffs* of the five bargaining 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.

Consider any two payoff pairs and some payoff pair on the line segment connecting them. The players can generate this payoff in the overall game by coordinating on an *intertemporal behavior* where they play each of the stage game outcomes a certain proportion of the time.[10] In general, the players can achieve any (almost, see previous footnote) payoff pair in the set of all convex combinations (the convex hull) of the stage game payoffs, by coordinating on different stage game payoffs different proportions of time. This is the region on and below the efficient frontier, shown by the line segments.

A simple but important fact is that there are many intertemporal behaviors (in continuous time, an infinite number) that ensure that different stage outcomes are selected 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. Since there is no exogenously given period structure, it is not a priori obvious for

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

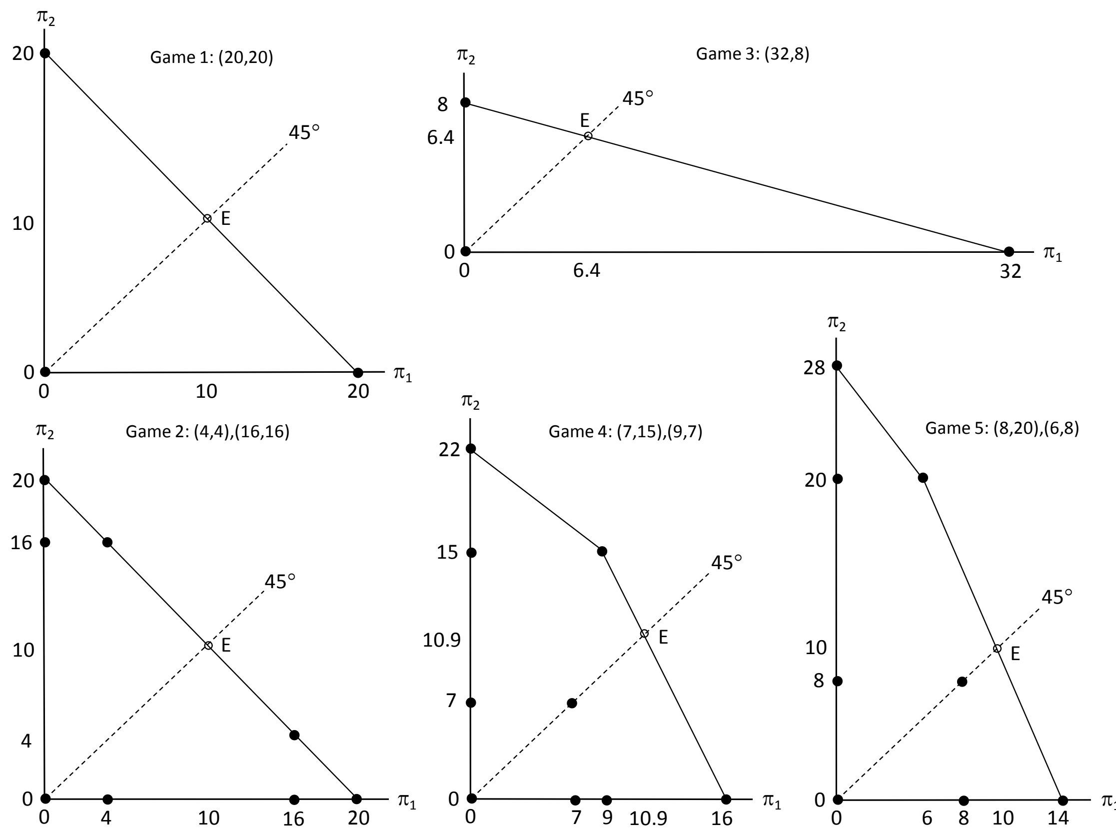

Figure 1: Feasible average payoffs in the five bargaining games. Black dots indicate payoffs that can be obtained from playing the same stage game outcome throughout the bargaining period. The solid line segments are the efficient frontier. The hollow dot is the equal and efficient payoff pair, *E*.

how long players should hold the asset before it is swapped. In addition to facing a coordination problem in selecting a pair of payoffs of the overall game, the players thus also face a coordination problem in selecting a specific intertemporal behavior achieving those payoffs, and both must be tackled tacitly and in real time.

3 Hypotheses

In this section we develop some hypotheses that help to guide the data analysis. Whenever we refer to 'payoffs', we mean average money earnings.

3.1 Payoff Focality

Table 2 shows for each of the five games (first column) the payoff pairs that we predict are potentially focal (the second column).[11]

In Games 1 and 2 we predict that (10,10) is strongly payoff focal since it is equal, efficient, and total payoff maximizing[12] and there are no other obvious payoff focal outcomes. Game 2 offers payoffs (4,16) and (16,4), but we predict they are too unequal to be focal.

In Game 3 the payoff pair $E = (6.4, 6.4)$ is potentially focal, since it is efficient and equal. Payoff pairs on the efficient frontier below E are unequal but offer larger total earnings than E; this may make them as if not more focal than E. On the other hand, we do not expect bargainers to find payoffs on the frontier above E focal, since these are as unequal as those below E and offer smaller total payoffs.

Game 4 has an equal payoff outcome, $(7, 7)$, but we predict that it is not focal since it is strictly dominated by the efficient equal outcome, $E = (10.9, 10.9)$, and by many other payoffs, such as $(9, 15)$. The efficient payoffs $(9, 15)$ and $E = (10.9, 10.9)$ are potentially focal. Any point on the efficient frontier between these payoffs cold also be seen by bargainers as focal, since it represents a compromise between equity and total payoff maximization.

[11] These are straightforward to compute—see Online Appendix 5.

[12] Recall again that efficiency refers to Pareto efficiency, measured in money terms, and that total payoff maximization implies efficiency, while the converse is not true.

Game	Potentially focal payoffs of overall game	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 overall 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: 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.

Finally, in Game 5 each of the payoffs $(6,20)$ and $E = (10,10)$ are potentially payoff focal. Points on the efficient frontier connecting them can also be focal (similarly to Game 4). We predict that payoffs on the efficient frontier above E are too unequal to be focal. Importantly, note that $(8,8)$ is not payoff focal since it is strictly dominated by $E = (10,10)$.

Assuming that only payoff focality is behaviorally relevant gives us the following benchmark hypothesis.

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.*
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 coordinate on payoffs* $(8,8)$, *since they are strictly dominated by* $E = (10,10)$.

We of course acknowledge that the experimental subjects may not be able to achieve perfect coordination on a given focal payoff pair, due to misunderstandings and the need to learn various features of the environment. These factors are likely to play a role regardless of whether coordination complexity matters or not. A weaker version of Hypothesis 1 is, therefore, that behavior in Games 1 and 2 will on average be the same, but not necessarily on the efficient frontier or concentrated exactly on payoffs (10,10). Similarly, behavior in the other games will be close to but not necessarily lie precisely on the parts of the efficient frontier described in Hypothesis 1.

3.2 Coordination Complexity

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

Consider some payoffs, $\pi = (x,y)$, of the overall game. 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 can distinguish between a *time-constant* intertemporal behavior, where the players play the same stage game outcome at every time instant, and a *time-varying* behavior, where the players coordinate on different stage game outcomes different proportions of time.[13] It is intuitively more difficult to coordinate on a time-varying than a time-constant behavior since the former requires that the assets are held by the players in the required proportions. Recall also, as pointed out in Section 2.3, that there are many intertemporal behaviors that achieve these aggregate proportions.

We hypothesize that players *ceteris paribus* avoid complex coordination behavior, and so will disregard a payoff focal pair π and coordinate on a pair π' that is less payoff focal but simpler to coordinate on if the benefits from reduced coordination complexity more than outweights the loss from getting lower payoffs. If, on the other hand, there are no sufficiently attractive payoff alternatives to π, then players cannot "escape" from the coordination complexity, and this may result in high coordination failure and low earnings, compared to the case where π had lower coordination complexity.

Consider first Games 1 and 2. Both have the same efficient frontier and the same payoff focal outcome, $E = (10, 10)$, but since Game 2 has more assets than Game 1, there are in Game 2 more time-varying intertemporal behaviors that generate payoff (10,10) than in Game 1 (see Table 2). In Game 2 subjects can avoid the high coordination complexity of $(10, 10)$ by instead settling on a simpler time-constant behavior giving payoffs $(4, 16)$ or $(16, 4)$. We predict, however, that these are deemed to be too unequal by subjects, so subjects will aim to coordinate on $(10, 10)$ but will be hurt by the larger set of time-varying intertemporal behaviors and that this results in lower earnings in Game 2 than in Game 1.

In Game 5 payoffs $(8, 8)$ are strictly dominated by $(10, 10)$, but while the former can be achieved by a time-constant behavior, the latter require a time-varying behavior. An observation that significantly more bargaining pairs tend to settle on a time-constant behavior giving payoffs equal or close to $(8, 8)$ than on a time-varying behavior giving payoffs equal or close to $(10, 10)$ indicate that coordination complexity is empirically relevant.

Consider also in Game 5 the payoffs on the line segment connecting payoffs (6,20) and (8,8). Such a payoff can be generated if the players co-

[13] A finer measure of coordination complexity would distinguish between different kinds of time-varying behavior, such as swapping assets, or one player sometimes holding both assets. In the analysis below we describe such different kinds of time-varying behavior.

ordinate on each of strategies (1,2) and (2,1) a certain proportion of time. That is, they swap the assets. With the exception of (6,20), all these payoffs are clearly strictly dominated by payoffs on the efficient frontier. Nevertheless, a time-varying behavior of swapping the assets seems simpler than the one required for getting on the efficient frontier, so coordination complexity may make the former behavior optimal. Thus we take a finding that a substantial proportion of bargainers tend to seek to coordinate on payoffs on the line segment connecting (6,20) and (8,8) as indicating the presence of coordination complexity. We summarize these hypotheses about the effects of coordination complexity here.

Hypothesis 2. *a. 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.*
b. In Game 5, significantly more bargaining pairs tend to coordinate on a time-constant intertemporal behavior giving payoff $(8,8)$ *than on a time-varying behavior giving payoffs* $(10,10)$.
c. In Game 5, a significant proportion of bargaining pairs tend to coordinate on a behavior where they swap the assets, which generates strictly dominated payoffs on the line connecting $(6,20)$ *and* $(8,8)$.

We can state an additional implication of coordination complexity. Suppose a substantial proportion of bargaining pairs in Game 3 coordinate on payoffs equal or close to $E = (6.4, 6.4)$. If only payoff focality matters, we would expect a similar proportion to do so in Games 4 and 5, since they exhibit the same qualitative trade-off between equality and total payoff maximization along the efficient frontier as Game 3.[14] However, in Game 4 (5) the payoffs $(9,15)$ ($(6,20)$) can be achieved through a simpler time-constant behavior than payoffs E. Thus, we interpret a finding

[14]We acknowledge that this comparison is imperfect since the exact payoffs differ. Nevertheless, we offer three observations that support the hypothesis. First, in Game 3 the outcome E offers payoffs 6.4 to each player, while it gives more, 10.9 and 10, in Games 4 and 5. Thus, *ceteris paribus*, if bargainers in Game 3 prefer to settle on E, they should also do so in Games 4 and 5. Second, reducing one player's payoff by one unit along the efficient frontier in order to increase total earnings, hence giving a new allocation E', produces a larger gain to the other player in Game 3 than in Games 4 and 5 (In Game 3 it gives four units to the other player, while in Games 4 and 5 the other player only gets 2.15 and 2.5, respectively). Thus, if in Game 3 bargainers consider that this gain is too small to make a deviation from equality desirable, such that they settle on E, then the same should happen in Games 4 and 5. Third, the ratio of total earnings in E' to E is higher in Game 3 than in Games 4 and 5; once more, if this gain is not sufficient to induce a deviation from E in Game 3, we expect the same to be true in Games 4 and 5.

that significantly fewer bargainers achieve payoffs equal or close to E in Games 4 and 5 than in Game 3, and that more bargaining pairs coordinate on payoffs $(9, 15)$ $((6, 20))$ than on E in Games 4 and 5, as indicating that coordination complexity plays an important role in Games 4 and 5. This gives:

Hypothesis 3. *Significantly fewer bargaining pairs coordinate on equal payoffs in Games 4 and 5 than in Game 3, and significantly more bargainers coordinate on payoffs* $(9, 15)$ *(*$(6, 20)$*) than on payoffs E in Games 4 (5).*

4 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 (2004)). 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.[15] 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 circles (see the screenshot in Figure 4 below).[16] Inside each circle was written

[15] 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 order effects, and therefore pooled the data.

[16] Similar representations have been used in other experiments; see Isoni et al. (2013),

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.

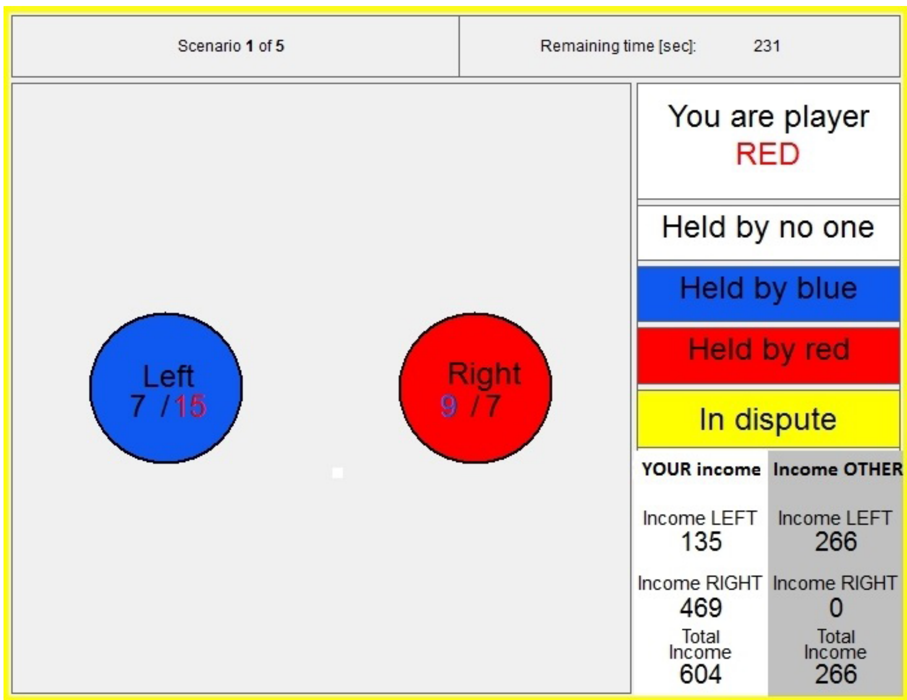

Figure 2: Screenshot. Objects were colored, as explained in the main text. The field "Held by no one" ("Held by Blue") ["held by Red"] [["in dispute"]] is colored white (blue) [red] [[yellow]].

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.

Isoni et al. (2014), and Mehta et al. (1994).

- 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.

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.

5 Results

5.1 Overview

The computer recorded every one-tenth of a second each player's decision, that is, the chosen stage game strategy. From now on "strategy" always means pure stage game strategy. For each bargaining pair, the *state* of bargaining at measurement time t is given by the *strategy profile*, that is, each subject's chosen strategy at that time.

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.[17] Closeness to the Efficient Frontier (CEF) is a measure of how close a payoff vector is to the efficient frontier.[18] In Games 1 and 2, TPE = CEF.[19] Earnings Inequality is the ratio of Player 1 and 2 earnings. 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) percent of the time. There are two sources of coordination failure in our bargaining environment, both

[17]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.

[18]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', 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 $\alpha = 0$.

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

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.

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

5.2 Game 1 and 2

In Game 1, Player 1 and 2's payoffs are close and not statistically significantly different (t-test, equality of means across pairs of subjects, $p = 0.21$), and Earnings Inequality is correspondingly close to 1. Within each bargaining pair the subjects tend to hold the asset the same amount of time

	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	1.03	1.08	1.76	0.69	0.61
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).

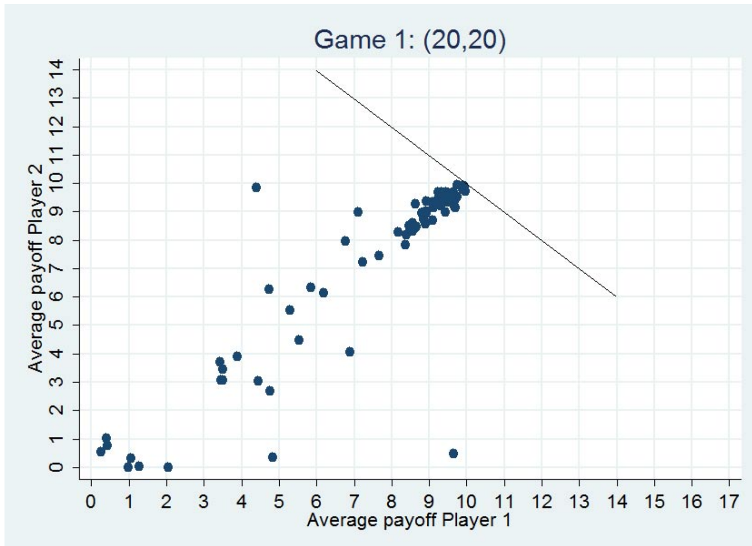

Figure 3: Scatter plot of Game 1 average payoffs pairs.

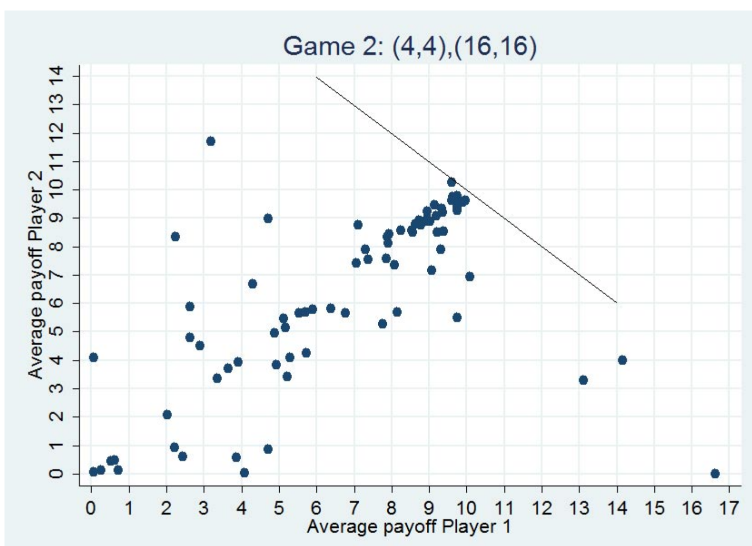

Figure 4: Scatter plot of Game 2 average payoffs pairs.

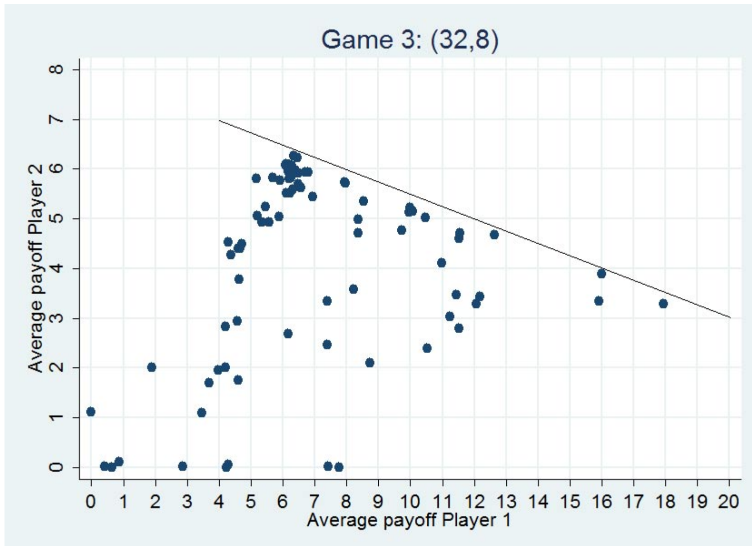

Figure 5: Scatter plot of Game 3 average payoffs pairs.

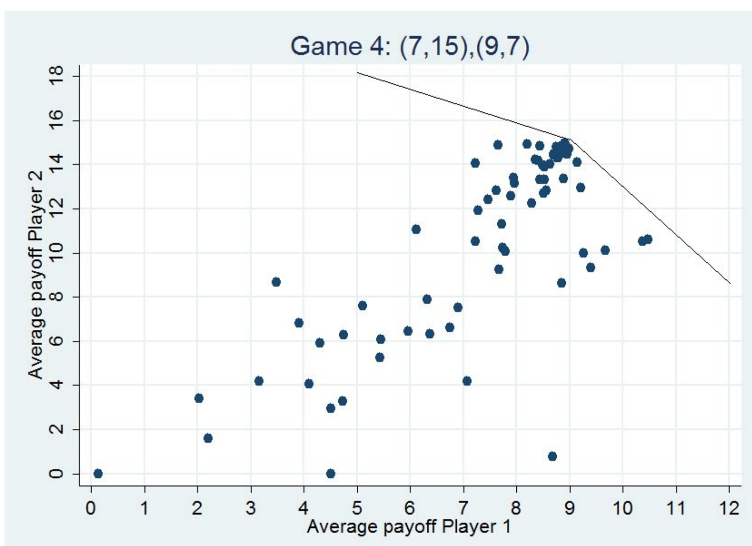

Figure 6: Scatter plot of Game 4 average payoffs pairs.

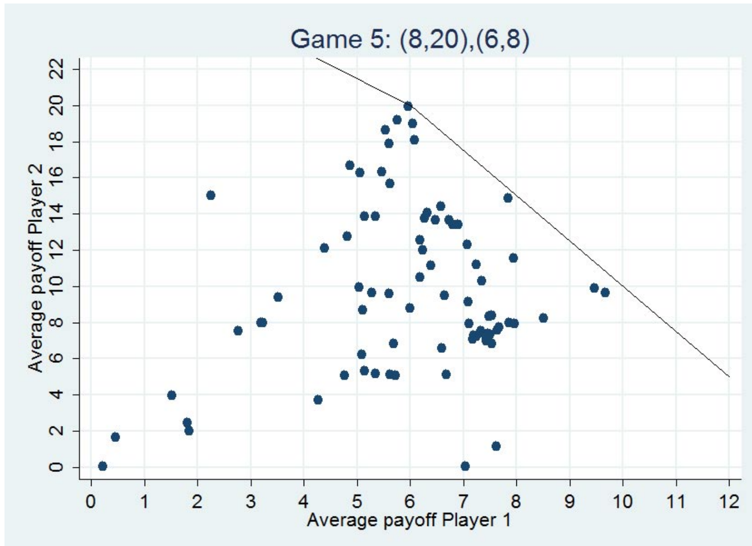

Figure 7: Scatter plot of Game 5 average payoffs pairs.

(between 36 and 38% of the time). The object is in dispute for almost all the remaining time; it is idle less than 2 percent of the time. Coordination failure is overwhelmingly due to dispute and not to assets lying idle; this is the case for all games.

In Game 2, average Player 1 and 2 payoffs are also similar (and not significantly different, $p = 0.14$), but, as can be seen in Figure 4, there is more dispersion than in Game 1, and some of this is due to some bargaining pairs seeking to settle on time-constant behaviors giving payoffs (4,16) or (16,4) but failing to get close to them. Furthermore, many payoffs on or close to the 45-degree line lie closer to the origin than in Game 1. This is reflected in lower average earnings, and lower TPE (=CEF, see Section 5.1) than in Game 1, primarily due to each asset being in more dispute in Game 2 than in Game 1. Total earnings and TPE=CEF in Game 1 are significantly higher than in Game 2 (one-sided test, $p = 0.029$).

Figure 4 and Table 3 show that in Game 2 very few bargaining pairs settle on a time-constant behavior giving payoffs (4,16) or (16,4). The most frequent behavior is instead that subjects alternate between strategy profiles (1,2) and (2,1), that is, they swap the assets. The subjects are thus quite able to overcome the coordination problem involved in selecting a time-varying intertemporal behavior, but there is still a significant amount of coordination failure that reduces payoffs below those obtained in Game 1.

We summarize these findings here.

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

5.3 Game 3

Figure 8 shows that in Game 3 a significant proportion of bargaining pairs cluster on an equal outcome on the 45-degree line, and that many get close to the 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 of E. The accumulation of behavior near E can be more clearly seen in the scatterplot in Figure 8 in Online Appendix 3, which for each bargaining pair shows the proportion of time the pair coordinated on 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 percent more than Player 2 (this difference is significant, $p < 0.001$, one-sided). On the other hand, Player 2 holds the asset more than twice as often as Player 1. The data thus reveal a tension between two potential payoff-based focal points, namely that Player 1 benefits four times as much from holding the asset than Player 2 (such that total payoff maximization implies that Player 1 should hold the asset all the time), and earnings equality (which means that Player 2 should hold the asset four times as frequently as Player 1, cf. Table 2). The fact that some bargaining pairs get stuck well below the efficient frontier can be interpreted as reflecting a disagreement about the relative importance of these two considerations. Finally, as predicted, no pairs find points on the efficient frontier above E to be focal.

In Games 1 and 3 Closeness to the Efficient Frontier is not significantly different ($p = 0.368$, one-sided test).[20] Since all potentially payoff focal outcomes have the same coordination complexity in these two games, this finding suggests that subjects are on average as able to avoid coordination failure when there is a range of potentially payoff focal outcomes on the efficient frontier as when there is a single payoff focal candidate. As shown by comparing Games 1 and 2, the detrimental impact on coordination is instead caused by differential coordination complexity. We summarize these results below.

Finding 2. *In Game 3, a significant proportion of bargaining pairs coordinate on equal and efficient payoffs E, but many bargainers settle on outcomes on or close to the efficient frontier that reflect a trade-off between inequality and total surplus maximization. Bargaining pairs are on average as able to get on the efficient frontier in Game 3 as in Game 1.*

5.4 Game 4

Recall the following intertemporal behaviors (cf. Table 2): the time-constant behavior where Player 1 holds Asset 2: $(9, 7)$ and Player 2 holds Asset 1: $(7, 15)$, i.e., strategy profile $(2, 1)$, giving payoffs $(9, 15)$; the time-constant behavior with the opposite pattern, i.e., strategy profile $(1, 2)$ generating payoffs $(7, 7)$; and the time-varying behavior giving payoffs $E = (10.9, 10.9)$, where Player 1 holds Asset 2 throughout the period, and Asset 1 is held by Player 1 a proportion $3/11$ of the time. In other words, the players coordinate on strategy profile $(2, 1)$ $8/11$ of the time, and on strategy profile (12,0) the remaining $3/11$ of the time.

Table 3 shows that coordination on strategy profile (2,1) is by far the dominant outcome—it is observed almost two thirds of the time on average. The percentage of bargaining pairs achieving coordination on strategy profile $(2, 1)$ at least 60, 70, 80, or 90 percent of the time are 62, 55, 50, and 36 percent, respectively. We can attribute the popularity of this outcome to it being efficient (total payoff maximizing, in fact), not excessively unequal, and achievable via a time-constant behavior.

[20]TPE is significantly higher in Game 1 than in Game 3 ($p < 0.001$, one-sided test), which is natural since many bargaining pairs in the latter game steer toward and get close to an equal outcome that in Game 3 clearly does not maximize total earnings.

Very few bargaining pairs achieve coordination on payoffs equal or close to $E = (10.9, 10.9)$. Table 3 shows that this happens only very rarely (less than 4% of the time). A closer look at the data reveals that only three bargaining pairs achieve payoffs to the northeast of (9,9).[21] Finally, strategy profile $(1, 2)$, that generates equal and inefficient payoffs $(7, 7)$, is on average observed less than 8 percent of the time. Bargainers do not sacrifice efficiency for equality.[22]

Finding 3. *In Game 4, a large majority of bargaining pairs achieve a high degree of coordination on the time-constant behavior giving payoff* $(9, 15)$*. Only a very small number of bargaining pairs achieve a high degree of coordination on the behavior giving equal and efficient payoffs, E. Finally, very few bargaining pairs coordinate on the time-constant behavior giving equal and inefficient payoffs,* $(7, 7)$.

5.5 Game 5

Once more, recall the following intertemporal behaviors: the time-constant behavior where Player 1 holds Asset 2: $(6, 8)$ and Player 2 holds Asset 1: $(8, 20)$, i.e., strategy profile $(2, 1)$, giving payoffs $(6, 20)$; the time-constant behavior with the opposite pattern, i.e., strategy profile $(1, 2)$ generating payoffs $(8, 8)$; and finally the time-varying behavior giving payoffs $E = (10, 10)$, where players coordinate on strategy profile $(2, 1)$ half of the time, and on strategy profile (12,0) the remaining half of the time.

Table 3 shows that in Game 5, bargaining pairs coordinate on 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 percent of the time do they coordinate on profile $(12, 0)$, where Player 1 holds both assets. These numbers are 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 coordinate only on strategy profile (1,2) or only on (2,1), or if the typical bargaining pair tends to coordinate on both profiles during the bargaining period.

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

[22] The percentage of bargaining pairs that achieve coordination on $(7, 7)$ at least 50% or 60% of time equal 6% and less than 1%, and no bargaining pairs coordinate on $(7, 7)$ more than 70% of the time.

The first (second) [fourth] row in Table 5 below shows the number of bargaining pairs who coordinated on strategy profile $(1,2)$ ($(2,1)$) [$(12,0)$] at least X percent of the time, where $X = 10, 20, ..., 90$. The third row gives the number of bargaining pairs that coordinate at least X% of the time on both strategy profile $(1,2)$ and $(2,1)$, where $X = 10, 20, 30, 40, 50$. The fifth row lists the number of bargaining pairs that coordinate at least X percent of the time on both strategy profile $(12,0)$ and $(2,1)$; recall that these strategies are required for generating payoffs $E = (10, 10)$.

Strategy Profile	10%	20%	30%	40%	50%	60%	70%	80%	90%
(1,2)	48	44	36	26	18	13	10	6	4
(2,1)	51	46	42	34	24	21	15	11	3
(1,2) and (2,1)	27	20	12	3	0	–	–	–	–
(12,0)	12	7	5	4	1	0	0	0	0
(12,0) and (2,1)	9	4	2	2	0	–	–	–	–

Table 5: Number of bargaining pairs in Game 5 that coordinated on strategy profile $(1,2)$, on $(2,1)$, on each of $(1,2)$ and $(2,1)$, on $(12,0)$, and on each of (12,0) and (2,1), at least X percent of the time, where $X = 10, 20, ..., 90$.

Thirty-three bargaining pairs (42%) coordinate on strategy profile (1,2) at least 60 percent of the time, and 20 pairs (25%) coordinate on the profile 70 percent of the time or more. Thus, a significant proportion of bargaining pairs achieve 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): 21 bargaining pairs (27%) coordinate on this strategy profile at least 60 percent of the time, and 15 pairs (19%) coordinate on the profile 70 percent of the time or more.

There is very little coordination on the payoffs $E = (10, 10)$. First, strategy profile (12,0) is observed very infrequently. Only 5 bargaining pairs (7%) achieve coordination on $(12, 0)$ 30 percent or more of the time. The data show that 49 bargaining pairs have a zero coordination rate on $(12, 0)$, and among the remaining 29 pairs the vast majority coordinate on $(12, 0)$ less than 5 percent of the time. See the histogram in Figure 9 in Online Appendix 3. Table 5 also shows that only *two* out of the 78 bargaining pairs get close to generating an equal mix of strategies (2,1) and (12,0); see also the scatterplot in Figure 11 in Online Appendix 3. We summarize these findings here.

Finding 4. *In Game 5, significant proportions of bargainers achieve coordination on a time-constant behavior giving either payoffs* $(8, 8)$ *or* $(6, 20)$*. Very few pairs achieve any significant coordination on payoff pair* $E = (10, 10)$*. These findings support part b of Hypothesis 2.*

It is also clear from Figure 7 that very few bargaining pairs achieve coordination on or close to *any* payoff on the efficient frontier, with the exception of $(6, 20)$. We can attribute this to the high coordination complexity of the required time-varying behavior, namely that one player must hold both assets a significant proportion of the time.

This does not, however, mean that there is no significant time-varying behavior going on. 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 $(2, 1)$. Each of these payoff is strictly dominated by payoffs on the efficient frontier. Table 5 shows that 20 pairs (about 25%) coordinate on each of these strategy profiles 20 percent or more of the time; 12 bargaining pairs (15%) coordinate on each strategy profile 30 percent or more of the time.

Finding 5. *In Game 5, almost no bargaining pairs coordinate on an intertemporal behavior that brings them close to the efficient frontier, with the exception of the time-constant behavior giving payoffs* $(6, 20)$*. Instead 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* $(6, 20)$*.*

Coordination complexity thus does not wipe out all time-varying behavior; rather, it leads to a selection among time-varying behaviors. Many bargainers seem to tacitly agree on a time-varying behavior that apparently is perceived as sufficiently simple so as to more than compensate for its strictly dominated payoffs.

It is interesting to compare the different relationships between efficiency and equality in Games 4 and 5. In the former game a large majority settle on an unequal but efficient outcome, $(9, 15)$, and avoid an equal and inefficient outcome, $(7, 7)$. Since these outcomes have the same coordination complexity, we can, as already mentioned, conclude that bargaining pairs are unwilling to sacrifice efficiency for equality.[23] In Game 5, outcomes $(8, 8)$ and $(6, 20)$ also have same coordination complexity, but the equal outcome is now efficient among outcomes with low (time-constant) coordination complexity, and this is enough to make it focal for a significant proportion of bargainers.

Finally, we can tie together the results already obtained and evaluate Hypothesis 3.

Finding 6. *While in Game 3 a significant proportion of bargaining pairs implement a time-varying behavior that brings them close to the efficient and equal outcome, $E = (6.4, 6.4)$, in Games 4 and 5 essentially no bargaining pairs coordinate on a time-varying intertemporal behavior required for generating the equal efficient payoffs, $E = (10.9, 10.9)$ and $E = (10, 10)$. This, together with Findings 3 and 5, supports Hypothesis 3.*

6 Conclusion

When two neighbours who cannot or prefer not to talk with each other every day need to decide when and for how long to use a common access way, parking space, waste recycling facility, or childrens' playground, then they are engaged in a real-time, non-cooperative, and tacit bargaining problem. The same situation is faced by a group of fishermen, each of whom must decide which fishing spots to use, and by two duopolists trying to tacitly coordinate on who should be the monopoly seller in which geographical district. Will a coordinated behavior emerge? Similar situations were informally described in Schelling's important book, *The Strategy of Conflict* (1960), but we are, to the best of our knowledge, the first to report experimental data on these bargaining situations.

Our findings, and the predictions they lead to for real-world tacit real-time bargaining situations, are intuitive and straightforward to explain. Two aspects matter: the decision makers' payoff opportunities and the complexity of coordinating on a behavior that achieves them over time, and subjects trade them off against each other.

The findings show that in general we cannot expect bargaining behavior in situations captured by our experimental bargaining environment to

[23] A similar finding, but in a cooperative bargaining environment, is reported in Galeotti et al. (2015).

be efficient—it will be constrained by coordination complexity. This in turn strongly suggests that when we seek to understand and predict behavior in these bargaining environments we must take into account the decision makers' cognitive constraints and their desire to settle on intertemporal behaviors with low complexity.

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7 Online Appendix

7.1 Appendix 1: Instructions

INSTRUCTIONS

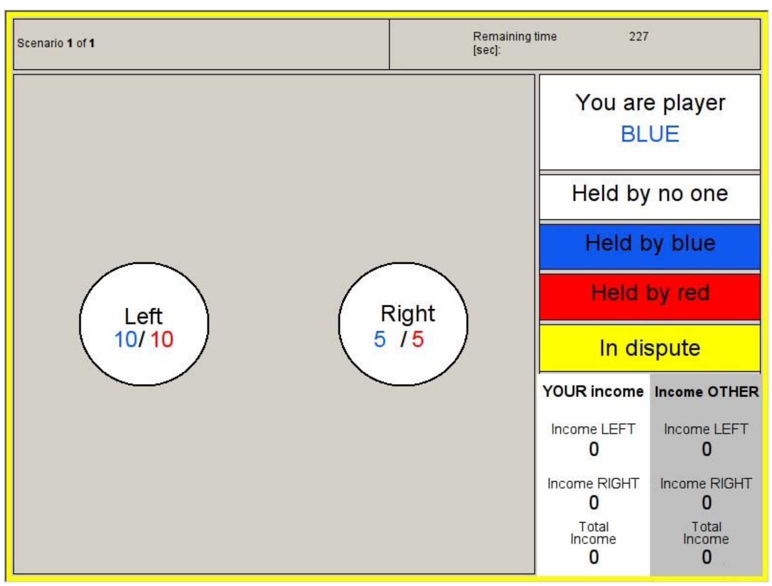
Welcome to this experiment. Please do not talk to any of the other participants, and please use the computer for the experiment only. The purpose of this experiment is to study decision making. You earn real money in this experiment. The amount of money you earn depends on your and on other participants decisions. Your money earnings will be paid to you in cash at the end of the experiment. All your decisions will be anonymous.

The Scenarios

You will make decisions in five scenarios that will be described below. In each scenario you are matched with one of the other people in the room. You will be matched with a *different* player in each scenario.

In each scenario there are two roles, the RED player and the BLUE player. Your color is randomly assigned, and you will keep it throughout the experiment. The assignment of colors has no impact on the task or your earnings.

In each scenario you and the other player that you are matched with for that scenario will see one or two *objects* (shown as circles) on your screens. An example is shown below. The two of you always see exactly the same objects, and they are always arranged in the same way on your screens. When there are two objects, each will have a name (Left or Right). Each object has two numbers written on it. These numbers are the objects *value* to each player.



The first number is always the value to the Blue player and is written in blue, and the second number is always the value to the Red player and therefore is written in red. This value is measured in *points*, and at the end of the experiment your income in points is converted into *income* in pounds. This is explained below.

Making Decisions in a Scenario

Each scenario lasts for four minutes (240 seconds). You can see the remaining time in the top-right corner. You can also see the number of the scenario (1 to 5) in the top-left corner.

In each scenario you can click with your mouse on an object. You can click on as many objects as you like, and as often as you like during the four minutes. The other player can do the same.

At the beginning of each scenario, all objects are white.

If you or your co-participant clicks on a white object, then that 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 held already by one of you (such that it has that players 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 players 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 players color.

Your Income from Each Scenario

Your income in points from a scenario depends on the value of the objects that you hold, and on how long you hold them. Objects that you do not hold—either because you have not clicked on them, or because they are in dispute—generate no income for you. As long as you are holding an object, you earn its value per unit of time. More precisely, the income is recalculated *every 10th of a second* and is added up. So, every 10th of a second where you hold an object, its value is added to your overall income. This is true for all the objects. So your total income is the sum of the total income from each of the objects.

On the screen you also see a table in the lower-right corner. There are two columns, one for you and one for the other player. Each column shows some numbers that will be updated over time. Each of these numbers shows your total income from each of the objects. The last number shows your total overall income from all objects. The specific numbers shown are just for illustration.

Moving from One Scenario to Another

When you have finished a scenario, you will see your point earnings from that scenario on the screen. You will then be matched with a different person in the room, and a new scenario then begins. You will not be told in advance what the scenarios look like.

Your Money Earnings

You receive £3 as a compensation for your time spent in the lab. Furthermore, at the end of the experiment, the computer randomly selects *one of the five scenarios*. Your total income in points from this scenario will be converted into pounds at the end of the experiment. Each point you earned as income will be converted into 0.053 pence. One pound therefore equals 1887 points.

You will be paid your money earnings privately in cash at the end of the experiment.

Please note: Since you do not know in advance which scenario will be chosen by the computer for payment, you should consider each scenario as equally important. Also, since each scenario is unrelated to the other scenarios, and you play them against different persons, you should consider each scenario on its own.

Tutorial

Before the first scenario begins we will show you a short, on-screen tutorial that explains the screen and how you make decisions in each scenario. The experiment will start once all participants have finished the tutorial. Please note that the scenario is just an example.

If you have any questions about the task or about the way your money earnings are determined, please raise your hand. The experimenter will then come to you and answer your question in private.

7.2 Appendix 2: Stage Game Payoff Matrices

	0	1
0	$0,0$	$0,20$
1	$20,0$	$0,0$

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

	0	1	2	12
0	$0,0$	$0,4$	$0,16$	$0,20$
1	$4,0$	$0,0$	$4,16$	$0,16$
2	$16,0$	$16,4$	$0,0$	$0,4$
12	$20,0$	$16,0$	$4,0$	$0,0$

Table 7: Payoff matrix for Stage Game 2: (4,4),(16,16).

	0	1
0	$0,0$	$0,8$
1	$32,0$	$0,0$

Table 8: Payoff matrix for Stage Game 3: (32,8).

	0	1	2	12
0	$0,0$	$0,15$	$0,7$	$0,22$
1	$7,0$	$0,0$	$7,7$	$0,7$
2	$9,0$	$9,15$	$0,0$	$0,15$
12	$16,0$	$9,0$	$7,0$	$0,0$

Table 9: Payoff matrix for Stage Game 4: (7,15),(9,7).

7.3 Appendix 3: Additional Figures and Data

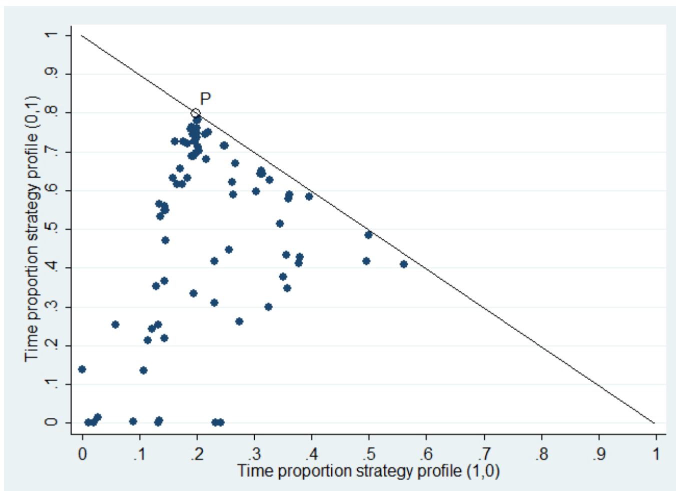


Figure 8: Scatterplot of the proportion of time each pair in Game 3 coordinated on the strategy profile $(1,0)$ and on the strategy profile $(0,1)$. The point $P = (0.2, 0.8)$ refers to the proportions that generate payoffs $E = (6.4, 6.4)$.

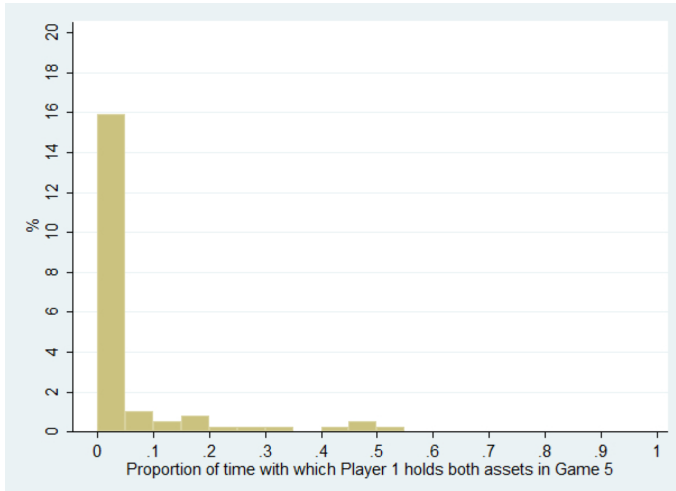


Figure 9: The relative frequency distribution of the time proportion with which a bargaining pair in Game 5 coordinated on the profile where Player 1 holds both assets (strategy profile $(12, 0)$).

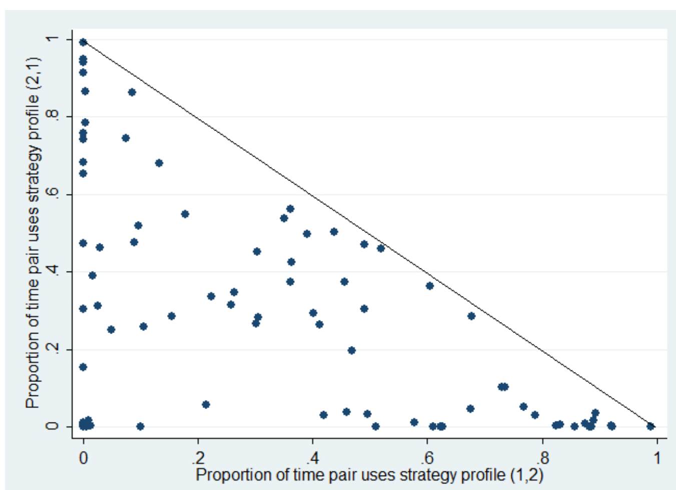


Figure 10: Scatterplot of the time each bargaining pair in Game 5 coordinated on the strategy profile $(1, 2)$ and on the strategy profile $(2, 1)$.

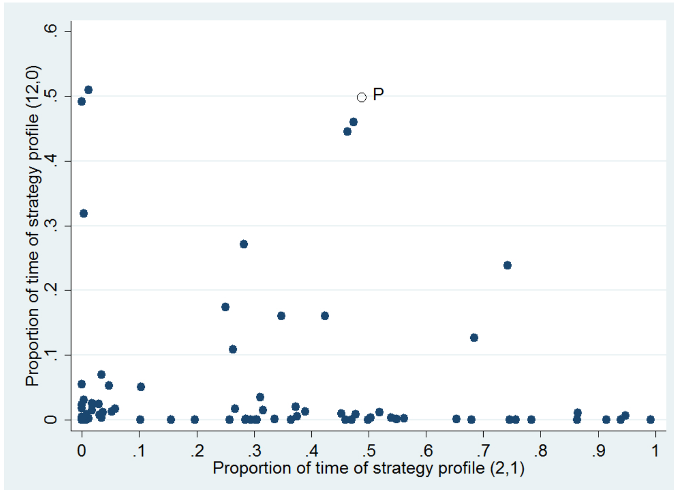


Figure 11: Scatterplot of the time each bargaining pair in Game 5 coordinated on the strategy profile $(2, 1)$ and on the strategy profile $(12, 0)$. The point $P = (0.5, 0.5)$ refers to the proportions that generate payoffs $E = (10, 10)$.

7.4 Appendix 4: Computation of Payoff Focal Intertemporal Behaviors

In what follows, stage game payoffs are abbreviated as SGP.

Game 1: In this game, the players can achieve equal and efficient payoffs of (10,10) if each player holds the asset half the time.

Game 2: In Game 2, there is large multiplicity of intertemporal behaviors that achieve payoffs (10,10). These differ in terms of the SGPs chosen. First, the players can coordinate on SGPs (0,20) and (20,0) half of the time. Second, the players can achieve the same if they coordinate on SGP (4,16) and (16,4) with the same proportions. Third, the players can coordinate on SGP (0,20) a proportion 3/8 of the time, and on SGP (16,4) the remaining proportion. Fourth, they can coordinate on SGP (4,16) a proportion 5/8 of the time and on (20,0) the remaining proportion. Fifth, they can coordinate on SGPs (0,20), (4,16), and (20,0) in such a way that if α and β are the proportions with which the two first SGPs are played, then $\alpha = (1/2) - (4/5)\beta$. Sixth, they can coordinate on SGPs (0,20), (16,4), and (20,0) by ensuring that $\alpha = (1/2) - (1/5)\beta$. Seventh, and finally, the players can play each of the SGPs (0,20), (4,16), (16,4), and (20,0) in proportions α_1, α_2, α_3, and $1 - \alpha_1 - \alpha_2 - \alpha_3$, satisfying $5 = 10\alpha_1 + 8\alpha_2 + 2\alpha_3$.

Game 3: Suppose Player 1 (2) holds the asset a proportion α $(1 - \alpha)$ of the time. Player 1 (2) payoff is then 32α $(8(1 - \alpha))$, so the players can achieve equal and efficient payoffs if $\alpha = 1/5$. Each player then earns a payoff of 32/5.

Game 4: In order to generate equal and efficient earnings, the players need to achieve a mix of payoffs (9,15) and (16,0). Suppose they coordinate on the former (latter) payoffs a proportion α $(1 - \alpha)$ of the time. Player 1 and 2's payoffs then equal $9\alpha + 16(1 - \alpha)$ and 15α, respectively. These are equal when $\alpha = 8/11$. Each player then earns $120/11 \approx 10.9$.

Game 5: Equal and efficient earnings require that the players establish a mix of payoffs (6,20) and (14,0). If they coordinate on the former (latter) payoffs a proportion α $(1 - \alpha)$ of the time, then payoffs are equal when $6\alpha + 14(1 - \alpha) = 20\alpha$, or $\alpha = 1/2$. Each player then earns a payoff of 10.