Efficient Coordination through ex post Negotiations

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Abstract

Synergies in production are ubiquitous in shared production processes such as those involving individuals within a team, departments within a firm, or industries within a country. Using a weakest-link game with ex post bargaining to redistribute the joint surplus we study a situation in which no central manager (or principal) can induce coordination through contracts, but instead team members themselves decide how to compensate each other. We show that standard bargaining theory (stationary equilibria) predictions do not provide a rationale for selecting efficient outcomes among the multiple Pareto-ranked equilibria. Nevertheless, we propose history-dependent bargaining strategies based on members' contributions which refine the set of equilibria selecting only the most and least efficient outcomes. An experiment reveals that ex post bargaining leads to enhanced efficiency compared to the benchmark weakest-link game. This is a particularly strong result since we implement a random subject rematching protocol. When efforts are not publicly known (due to monitoring costs for example) average effort falls close to that observed without bargaining and a similar result holds when the distribution of the surplus is private information.

I. Introduction

Collectivities often operate under conditions in which coordinated actions among their members are crucial for attaining highly efficient aggregate outcomes. The need to coordinate is particularly salient in productive processes characterized by the presence of complementarities or synergies between inputs which are often present in joint tasks performed by partners in a team, departments within a firm, or sectors within an economy.[1] It is well-established that when shared production processes display both complementarities in strategic decisions and externalities, game theoretic models usually display multiplicity of equilibria (Cooper and John 1988, Milgrom and Roberts 1995), rendering standard notions of equilibrium ineffective for predictive purposes. Since teams, firms, and countries can end up steady in suboptimal outcomes, it becomes crucial to understand which mechanisms or institutional variables are conducive to selecting equilibria that are better for the collectivity in terms of welfare.

In this article we provide a theoretical framework and conduct laboratory experiments to study coordination possibilities when claims to a jointly produced surplus are defined ex post via bargaining in the absence of a central authority, and importantly, in which production is not additively separable so that it is not clear *who produced what*. Can a group of individuals achieve efficient coordination by governing themselves through ex post negotiations despite the conflicting views of fairness that may arise?

We study a setting that resembles a team production process through voluntary contributions or effort choices with a democratic redistributive process: ownership rights over the surplus created are undefined but all members have *equal bargaining rights*.[2] Thus, collective

[1] At the aggregate economic level, the role of synergies across productive sectors are essential to attain high productivity levels as evidenced in the seminal paper by Hirschman (1958) on the role of backward and forward linkages. See also Rodríguez-Clare (1996a,b) for the role of production complementarities in economic outcomes of small open economies.

[2] In our model we abstract away from the formation process of the alliance, team, or firm. Moreover, we study the case where all of production is subject to ex post renegotiation. It would be straighforward to extend our model to the case where part of the surplus is allocated according to some preestablished property rights.

production yields a surplus from which agents can be excluded ex post but all are equally likely to influence the final outcome ex ante. Specifically, we endogenize the origin of the fund to distribute via a weakest-link game (Bryant 1983, Hirschleifer 1983, van Huyck et. al 1990), an extreme case of productive synergies in which the player exerting the lowest effort (or investment) determines the total output. As Knez and Camerer (1994) argue, the weakest-link game serves as an abstraction that captures a wide range of shared production processes in firms and teams. Quite importantly, our mechanism is budget balanced which implies that we can find bargaining equilibria that sustain full efficiency but it is not possible to rule out the least efficient outcome as an equilibrium because there would be no resources to *punish* non-contributors.

After production has taken place, team members negotiate according to the protocol of alternating offers and voting developed by Baron and Ferejohn (1989; BF hereafter).[3] It is well known that multilateral bargaining games of sequential offers and voting, such as the BF model studied here, display multiplicity of subgame perfect equilibrium outcomes (Sutton 1986; BF 1989; Eraslan 2002), namely that any division of the surplus can be sustained. Thus, which equilibrium is selected (coordinated upon) in the bargaining game can in turn affect which effort levels are provided in the weakest-link surplus-creation stage. In this sense our game presents a unique setting to study a *dual equilibrium selection problem*: how bargaining strategies affect initial efforts and vice-versa.

One natural conjecture is that adding a strategically complex bargaining game further complicates the possibility of coordination in the production game because of the added ambiguity about others' strategies. More importantly, the plurality of fairness ideals which have been identified in previous divide-the-dollar experiments with production (Capellen et al. 2007) may lead to bargaining outcomes which are viewed as fair by some subjects

[3] One can implement other bargaining protocols such as an offer and exit model by Krishna and Serrano (1995) or the demand bargaining game by Morelli (1999). We focus on the Baron and Ferejohn closed-rule bargaining game because it has received wide attention within the theoretical literature (Eraslan 2002, Yildirim 2007; Merlo and Wilson 1995; Eraslan and Merlo 2002; Baranski 2016) and the experimental literature (Fréchette, Kagel, and Morelli 2005a,b,c; Agranov and Tergiman 2014; Baranski and Kagel 2015; Bradfield and Kagel 2016).

and unfair by others, which in turn may attenuate incentives to exert effort into the joint task. A growing literature on bargaining over an endogenous fund, reviewed in Section 2, has focused on linear production technologies where it is quite transparent what portion of total output each player is accountable for. Even in such settings, a considerable variety of distributional schemes arise, and thus, understanding how value-sharing decisions in the presence of complementarities affect effort provision is an important aspect on which our experiment contributes.

Intuitively, the presence of synergies as modeled by the weakest-link game may foster harsher punishment towards low contributors compared to the linear production case because of the negative externalities that a low contributor imposes, and it is not clear *a priori* if such dynamics could incentivize subjects to invest or instead dissuade them due to the fear of punishment. It is also unclear at the onset if high contributors will be rewarded given the fact that part of their efforts are wasteful and only reflect unmaterialized efficiency gains. Moreover, the implementation of redistribution schemes proportional to individual efforts need not lead to profitable returns while such schemes always lead to positive returns in the linear case. Thus, the results from previous experiments in which production inputs are perfect substitutes (Baranski 2016, 2018) need not transfer to the perfect complements case and only with controlled experimentation can we identify the effect of varying the production technology.

In the article, we explore theoretically how various bargaining strategies based on previously documented fairness ideals can affect the set of equilibrium effort choices. Since our bargaining game admits any allocation as part on an equilibrium, we do not need to resort to modifying players' utility functions to descriptively fit our findings ex post (e.g. Fehr and Schmidt 1999, Bolton and Ockenfels 2000). We show that bargaining strategies stemming from an egalitarian fairness ideal, either an equal split or a split that minimizes final payoff differences, do not refine the set of equilibrium effort choices and neither does the stationarity refinement typically assumed in models of multilateral of bargaining. However, efficient coordination can be selected under bargaining strategies that resemble ideals of fairness in which higher contributors are rewarded with larger shares of the fund. These bargaining strategies are rooted in psychological notions of inequity (Adams 1963; Selten 1987) and punishment (Fehr and Gächter 2000, 2002). Importantly, we designed our experiment such that the proposed strategies do not rule out the secure equilibrium[4] of zero effort which implies that our experimental inquiry of the weakest-link game remains one of equilibrium selection under any strategy specification in the bargaining subgame.[5]

Our line of inquiry diverges from previous studies that have highlighted the role of centralized management[6], such as Milgrom and Roberts (1995) who state that their "results also suggest a reason why change in a system marked by strong and widespread complementarities may be difficult and why centrally directed change may be important for altering systems (pgs. 190-191)."[7] Most experimental studies have focused on the effect of centralized decisions with ex ante commitment such as the exogenous implementation of financial incentives to coordinate on efficient outcomes (e.g. a performance bonus) as in Brandts and Cooper (2005) or the role of a manager in endogenously fostering coordination through bonuses and communication channels as in Brandts and Cooper (2006). The experiments conducted here provide an affirmative answer to our question on the effectiveness of ex post multilateral bargaining to coordinate on *better equilibria*: subjects achieve high efficiency gains when they can negotiate the division of a jointly produced surplus compared to the implicitly preestablished equal division.

[4] An equiibrium is secure according to van Huyck et al. (1990) if all players choose the effort level that makes them best off in the worst possible profile of efforts chosen by others.

[5] This design feature was carefully chosen because we wished to capture the essence of the previously observed dynamics in standard weakest-link games. We can show that regardless of the bargaining strategies employed, the risk-dominant action of no effort always remains an equilibrium of the game. This only holds when the total surplus is zero if at least one player chooses the lowest effort which is the case in our main treatments. In a follow-up treatment, we introduced an exogenous component such that the total fund to distribute would be positive even if the minimum effort was zero and find evidence of a reduction in the choice of zero effort and an increase in amount of maximum effort choices, with average investments being marginally higher.

[6] The role of the entrepreneur as a centralized, non-market coordination device was seminally proposed by Coase (1937) when he described the nature of the firm.

[7] Similarly, Alchian and Demsetz (1972) argue that in a team production process "[o]ne method of reducing shirking is for someone to specialize as a monitor to check the input performance of team members (pg. 781)".

Three main experimental treatments were conducted to test the role of redistributive bargaining on effort choice. In the first treatment, subjects made effort decisions (or investments) and proceeded to bargain over the distribution of the fund with public information about the everyone's investment decision. In a second bargaining treatment, individual investments were not observable, only the total fund. Next, we conducted a benchmark treatment corresponding to the canonical weakest-link game without bargaining. Based on previous studies we believe that our experimental design is such that coordination (i.e. all group members making the same effort choice) is difficult to achieve, more so at efficient levels. First, we implement a strangers matching protocol so that reputation concerns within the experiment are mitigated. Second, the effort choice set is typically restricted to seven or less choices in the previous studies, but our experiment allows a much larger range of effort choices which substantially diminishes the possibility to coordinate on any given level. Last, our design guarantees that the security refinement selects zero effort as the unique equilibrium in every treatment regardless of the bargaining subgame equilibrium.

The data show that ex post bargaining gives rise to large efficiency gains as measured by subjects' investments which are close to 65 percent of their endowment on average. In the control treatment, investments rapidly decline and average 5 percent of endowment (both results are for the last 5 out of 10 games played by subjects). Most subjects assign shares of the fund based on a priority rule defined by member's contributions. We also find evidence for the implementation of a proportionality standard of redistribution in which a player's share is proportional to her investment relative to the aggregate investments, but this mode of behavior is more often observed in the experiments with a linear technology.[8] Opportunistic behavior, in which a minimum winning coalition excludes the highest contributors, represents only 8 percent of observed bargaining outcomes. As further evidence in favor of our investment-based bargaining theory we find that in the absence of a collective and public history of efforts, bargaining leads to very low effort choices.

[8] The proportionality standard is also referred to as *liberal egalitarianism* in Capellen et al. (2007) which "holds that only inequalities that arise from factors under individual control should be accepted. (pg. 818)"

The article proceeds as follows. Section 2 presents a literature review on the weakest-link game, bargaining *á la* Baron and Ferejohn, and other experiments on bargaining over an endogenous fund. Next, we provide the theoretical setup in Section 3 followed by our equilibrium characterizations in Section 4 which will serve as our testable hypotheses for experimental evaluation. Section 5 describes the experimental procedures. The results for the main treatments are presented in Section 6 where we also relate our current results to those of Baranski (2018), especially focusing on the differences in bargaining behavior when production is additive. Finally, Section 7 concludes the article.

II. Previous Literature

To study synergies in production we employ the classical weakest-link game (also known as the minimum effort game) in which the total surplus available to a group is determined by the member exerting the lowest effort. This game, as proposed by Hirshleifer (1983), was originally formulated in the context of a public good provision problem in which the surplus was shared equally among all members of the group. Simultaneously, Bryant (1983) proposed it as the production process of an intermediate good in a Keynesian model with multiple sectors in the economy. In the words of Bryant, "[t]his production technology is, of course, very artificial and simple. Nevertheless, it may capture the essence of the specialized, multi-staged, and decentralized production that characterizes an advanced economy" (pg. 526). Importantly, it can be shown that the fixed proportions characteristic of this technology is a limiting case of the well-known Cobb-Douglas production function as shown in Cornes (1993).

Besides its relevance in the fields of Political Economy, Macroeconomics, and Organizational Behavior, the weakest-link game has been a workhorse model in game theory and experimental economics used to study problems of coordination and equilibrium selection. It predicts multiple Pareto-ranked equilibria ranging from the lowest to the highest attainable efficiency. Since higher levels of effort are more costly than lower levels, members who seek to be safe and maximize their well-being in the worst case scenario will actually exert the lowest level of effort (as predicted by the risk dominance selection criterion). Some might argue that the efficient outcome can be focal in the sense of Schelling (1960), but ultimately which equilibrium will be played is an empirical question suitable for study under controlled experimentation.

The experimental literature, which started with the seminal paper by van Huyck, Battalio, and Beil (1990), has offered strong evidence in favor of the risk-dominant equilibrium given the low effort levels typically observed after a few repetitions of the game except in very small groups in which efficient coordination is modal (see Weber (2006) for a concise review).[9] In groups of two and three with random partner matching, Goeree and Holt (2005) find that reducing the cost of investing increases the minimum effort, even when there is no change in the Nash predictions.[10] It has also been reported that when teams play the weakest-link game against other teams, substantial efficiency gains arise (Feri, Irlenbusch, and Sutter 2010).

Several mechanisms that promote coordination on the efficient equilibrium have been studied in the laboratory such as intergroup competition (Bornsteing, Gneezy, and Nagel 2002), implementing a bonus (Brandts and Cooper 2006a), starting in small groups and expanding to larger groups (Weber 2006), pre-play communication (Blume and Ortmann 2007), and endogenous group formation (Riedl, Rhode, and Strobel 2016).[11] This latter study by Riedl, Rhode, and Strobel is particularly relevant to ours because it allows for ex ante exclusion on the benefits produced, while our game allows for ex post exclusion through bargaining. The enhanced efficiency levels they observe are explained through social ostracism based on history: those who exerted low effort in the past are excluded from the

[9] See Engleman and Norman (2010) for a study with a sample of Danish students which lead to efficient coordination thus showing that cultural norms may alter the equilibrium selection process in this game.

[10] The authors designed their experiment to test a generalized version of the risk dominance equilibrium selection criterion and find that a decreased cost of effort reduces cost of "mistakes" thus making higher efforts more attractive compared to the case when the cost is high.

[11] Croson, Fatas, Neugebauer (2005) show that an unexpected restart of the experimental session will also lead to an increase in effort provision, which will decay with repetition.

possibility to take part in productive endeavors with others. Our experiments reveal that a similar mechanism is at play with ex post bargaining, namely the fear of exclusion based on the expectation that bargaining outcomes will punish low contributors, an expectation which materializes through an implicit coordination on bargaining strategies.

Other experimental studies of the weakest-link game have investigated whether advice may increase efficiency. Weber et al. (2001) find that a group leader that publicly reads a message asking members to choose the highest effort does not have a meaningful impact on effort, and Chaudhuri, Shotter, and Sopher (2008) show that intergenerational advice has a limited effect as well. Deck and Nikiforakis (2012) report that real-time monitoring of others' effort choices leads to higher levels of effort but only if information is perfect.

As previously stated, the Baron and Ferejohn model of bargaining has multiple equilibria: any allocation of the surplus can be sustained as a subgame perfect Nash equilibrium given that players are patient enough. The theoretical literature has mainly focused on history-independent strategies since a unique subgame perfect equilibrium outcome is derived which yields an expected value equal to the total surplus divided by the number of members in the committee. This expected value coincides with the same payoff structure as the standard weakest-link game with preestablished equal shares. As such, there is no role for ex post bargaining in equilibrium selection of the weakest-link game under the stationarity refinement.

While history-independent bargaining strategies have been universally adopted in the theoretical bargaining literature[12], and have been the object of multiple experimental inquiries (Diermeier and Morton 2005; Fréchette, Kagel, and Morelli 2005a,b,c; Miller and Vanberg 2013) the experiments in Baranski (2016, 2018) show that when the fund to distribute is endogenous in the BF game, such strategies do not accurately describe subjects' behavior.[13] In the Baranski experiments, the total fund was endogenized via individual in-

[12] See for example Merlo and Wilson (1995), Eraslan (2002), Jackson and Moselle (2002), Volden and Wiseman (2007), and Britz, Herings, and Predtetchinski (2013) all who assume stationarity.

[13] For Baron and Ferejohn experiments with pre-play communication see Agranov and Tergiman (2014) and Baranski and Kagel (2015). For heterogenous disagreement values see Miller, Montero, and Vanberg

vestments which were summed up to determine the total fund (investments are efficiency enhancing). Importantly, the linear aggregation technology is tantamount to the inexistence of synergies in production, thus the dilemma faced at the production stage is not one of coordination. Those experiments revealed that redistribution strategies were largely conditioned on initial efforts: higher efforts were rewarded with higher shares of the fund[14], but strategic behavior in the form of minimum winning coalitions was also visible.

Under the weakest-link production technology the exclusion of low investors and the proportional redistribution strategies are also plausible, yet, do not always entail effort-inducing incentives because the available fund may be insufficient to cover the aggregate effort costs. In the extreme case in which one player exerts no effort, there is no surplus to disburse among the remaining members. Thus, the dynamics that gave rise to large efficiency gains in the linear setting are quite fragile with extreme partner synergies.

Our experiment is also related to a growing literature on the distribution of an endogenous fund. In simple dictator games, Cappelen et al. (2007) assign subjects to different marginal productivities in a linear production setting in order to identify various fairness ideals from observing subjects' ex post allocations. For example, the libertarian ideal would imply a distribution of the joint production according to individual production. Importantly, this ideal can only be concretely applied in an additively separable production setting, but not in the weakest-link setting in which it is not clear *who produced what*. The liberal egalitarian principle disregards differences in productivities and assigns the output proportionally based on individual contributions. In our theoretical setting, we propose a proportional redistribution scheme in which the total surplus is split according to the ratio of own effort to aggregate effort, much in line with this principle. Cappelen et al. (2007) also consider

(2018). For a comparisson between the closed and open amendment rules see Fréchette, Kagel, and Lehrer (2003). See Bradfield and Kagel (2015) for an experiment when teams bargain. For experiments with policy proposals and private goods see Christiansen, Georganas, and Kagel (2014).

[14] In the linear setting, the proportional redistribution strategies are equivalent to a piece-rate contract. Since there are no complementarities in production, each player can fully appropriate the surplus she generated. Hence, the unique equilibrium under proportional redistribution strategies is fully efficient.

the egalitarian outcome which they characterize as an equal split of the total fund.[15] The main finding that they report is that there is considerable plurality in fairness ideals even among a relatively homogeneous population of business students and that standard models of inequality aversion (Fehr and Schmidt 1999; Bolton and Ockenfels 2000) are not useful in explaining the results. Konow (2000) and Frolich, Oppenheimer, and Kurki (2004) also investigate behavior in dictator games with joint production and Gantner, Güth, and Königstein (2001) implement ultimatum and demand bargaining protocols. All these studies report a significant tendency of subjects to derive entitlements from their own investments.

In bilateral negotiations with unstructured protocols, the experimental study of Gächter and Riedl (2005) is relevant to ours with the caveat that the total fund is portrayed in the instructions as if it was jointly produced, but no production function is explicitly described. In their study, subjects participated in a quiz in which the highest performer would earn 1660 tokens and the lowest performer only 830. However, there was a chance that the total budget for both payments was lower (2050 tokens) case in which the experimenter would not impose a division and subjects would have to reach an agreement themselves. In other words, when the claims of 1660 and 830 were infeasible, free-from negotiations would take place. The authors find that initial entitlements have a strong impact in bargaining outcomes by altering initial offers and concessions throughout the process. In a similar quiz design, Karagözoglu and Riedl (2014) did not provide exogenous entitlements, but allowed them to form endogenously. They varied the information available about individual quiz performance and found that subjective claims were more likely to be derived in settings with high information and less likely to be derived (and subsequently impact bargaining outcomes) when subjects were unaware of who performed better in the team.

In structured multilateral bargaining, Gantner, Horn, and Kerschbamer (2016) designed an experiment to test how different bargaining protocols perform when the total surplus is jointly generated. Subjects participated in an individual quiz but were graded according

[15] We depart from this definition and instead characterize the egalitarian outcome as the distribution of the fund which equalizes *final wealth holdings.*

to their performance relative to members of their cohort. Afterwards, subjects from different cohorts were matched in three-person committees and the total surplus was determined through a non-linear function of the points earned in the previous quiz. The goal of the researchers was to create an environment conducive to the emergence of conflicting subjective views on how to split the total fund in order to investigate which protocols would lead to more efficient bargaining outcomes (i.e. less delay). Answers to survey questions (from stakeholders and also from impartial spectators using a vignette technique) clearly showed that there were conflicting views especially when all group members earned different points in the quiz. The authors find that the bargaining protocol proposed by Shaked (an extension of the bilateral bargaining model by Rubinstein (1982) to three players in which players sequentially take turns at making proposals and voting) performed better compared to the others in terms of fairness since it leads to outcomes which are closer to the elicited fair outcomes. In terms of efficiency, all protocols were quite similar.[16] The authors did not consider the Baron and Ferejohn (1989) model, and furthermore, subjects were unaware of the bargaining protocol they would face prior to answering quiz questions, thus no expectations about bargaining outcomes were formed at the surplus creation stage.

III. The Model

Let there be n (odd) number of players indexed by i which are endowed with a unit of wealth normalized to 1. The game has two main stages. In the first stage, players simultaneously and independently choose an effort level $e_i \in [0, 1]$. The total fund is determined as follows

$$F(\mathbf{e}) = \alpha n e_{\min}$$

where $\alpha > 1$, $e_{\min} = \min\{e_1, ..., e_n\}$, and bold letters denote vectors as usual (the dimension of the vector can be inferred from the context). The parameter α can be interpreted as a

[16] The other protocols were the models of multilateral bargaining by Krishna and Serrano (1996) and demand bargaining by Torstensson (2009).

productivity measure. We will only consider linear costs in this article, thus we normalize the marginal cost of effort to 1.

Subsequently, if $F(\mathbf{e}) > 0$, players proceed to a bargaining stage which is divided into bargaining rounds denoted by $t \in \{1, 2, ...\}$. In each round, a player i is recognized as the proposer with probability π_i. The proposer submits an allocation $(s_1^t, ...s_n^t) \in S(\mathbf{e})$ where s_j^t denotes the monetary amount offered to player j and $S(\mathbf{e}) := \{(s_1^t, ...s_n^t) \text{ s.t. } \sum_{i=1}^n s_i^t = F(\mathbf{e})\}$ is the set of feasible, non-wasteful allocations. Next, players proceed to vote by choosing $v \in \{yes\ ,\ no\}$, and if the proposal received q votes, then it is approved and the result is binding. If the proposal is rejected, a new bargaining round takes place, with the proposer again being randomly selected. The process continues until approval.

In order to properly define the strategy space we let h_t be the history of play up to bargaining round t which includes all the previously rejected proposals, the identity of the proposers, and the distribution of votes. At the start of the bargaining stage, the history contains only the vector of efforts. At the voting stage, the history also contains the current proposal and proposer's identity. We denote by H_t the set of all possible histories up to period t.

Formally, a proposal pure strategy in round $t \geq 1$ is defined as a function $s^t : H_t \rightarrow S(\mathbf{e})$ and a voting strategy is defined by $v^t : \{H_t, S(\mathbf{e})\} \rightarrow \{yes\ ,\ no\}$.[17] A strategy profile $\boldsymbol{\sigma}^\tau = (\mathbf{e}, s^\tau, v^\tau)$ which leads to approval of a proposal in round τ yields to player i

$$u_i(\boldsymbol{\sigma}^\tau) = \delta^{\tau-1} s_i^\tau + 1 - e_i$$

where $\delta^{\tau-1} s_i^\tau$ is the discounted value of the share received from the common fund and $1 - e_i$ is the amount not invested (alternatively, the leisure enjoyed). The interpretation of this model is that players consume or enjoy their leisure (or the amount not invested) immediately while the returns from the total fund are realized only after reaching an agreement. If the strategy profile never leads to approval, each player earns $1 - e_i$. As usual, $\delta \in [0, 1]$ represents the

[17] The standard assumption in the literature is the players vote in favor whenever indifferent.

discount factor.

IV. Equilibrium Characterizations

In this section we present our theoretical hypotheses based on different specifications of equilibrium behavior in the bargaining subgame. Given the nature of the game and the multiplicity of equilibria, our hypotheses are about what kind of bargaining behavior is consistent with the different levels of effort provision, in particular, which strategies may lead to full efficiency.

Our focus will be on pure strategies in the effort stage. A relevant aspect to notice is that in the specification of strategies, the vector of contributions $\mathbf{e}$ is a dependent variable, thus we have implicitly assumed that each player's contribution is publicly known. For each characterization we provide, we will also discuss the role of observability of other's efforts.

Remark 1 It is straightforward to notice that regardless of the bargaining strategies, the vector $\mathbf{e} = \mathbf{0}$ is always an equilibrium in our setting. Moreover, the security criterion selects $\mathbf{e} = \mathbf{0}$ as the equilibrium no matter what strategies are implemented at the bargaining stage. This parametrization was chosen in order to guarantee multiplicity of equilibrium effort vectors (regardless of the bargaining strategies employed) and to ensure comparability with other weakest-link experiments in which the security criterion is relevant. In one of our treatments we introduce an exogenous component such that under certain bargaining strategies, the security criterion has no bite.

IV.a Stationary Subgame Perfect Equilibria

We start by restricting attention to strategies which are subgame perfect, i.e. from which there is no profitable deviation at any point in time, and also stationary meaning that strategies are not dependent on the current period or history of play (denoted by SSPE).

This last assumption selects a unique equilibrium outcome in the bargaining subgame up to a permutation of the players' identities (see Baron and Ferejohn 1989; Eraslan 2002).

In this equilibrium, the proposer offers $\delta F(\mathbf{e})/n$ to $q-1$ coalition members chosen randomly and keeps the rest. Proposals only depend indirectly on the effort vector $\mathbf{e}$ because efforts determine the size of the fund to distribute and the sum of shares must exhaust the fund. One can express amount received as a percentage share of the total fund through a normalization, thus making it salient that bargaining strategies are independent of $\mathbf{e}$. All coalition partners vote in favor including the proposer and the proposal is approved without delay.[18]

Now that we have characterized equilibrium in the bargaining subgame we can compute the resulting ex ante value of the game (i.e. the expected payoff prior to the first proposer being selected) which equals the average fund given by $\alpha e_{\min}$. Hence, a player's total expected payoff is $\alpha e_{\min} - e_i + 1$ which is the standard payoff in the weakest-link game with a unit cost of effort.[19] The lemma we present next follows from the analysis above.

Lemma 1 Under the stationary subgame perfect equilibrium of the bargaining game, any symmetric vector of efforts $\mathbf{e}$ can be sustained in equilibrium.

While stationarity selects a unique equilibrium configuration in the bargaining subgame it does not reduce the set of equilibria in the effort stage.

IV.b Subgame Perfect Equilibria

We now allow for bargaining strategies to be history dependent, yet still require them to be subgame perfect. As Baron and Ferejohn show in Proposition 2 of their article, any allocation of the surplus can be sustained as a subgame perfect Nash Equilibrium as long as

[18] Delay can be sustained in equilibrium for the case $\delta = 1$, yet the characterization of equilibrium payoffs remains.

[19] The result is trivially generalized for other cost structures.

$n \geq 5$ and δ is large enough.[20] In other words, for any given distribution of the total fund $\mathbf{s} = (s_1, ..., s_n)$, there exists a punishment strategy for players that deviate from making such proposal or enforcing the punishment strategy (we do not repeat here the off-equilibrium punishment strategy thus our strategies will be incompletely specified). Given the multiplicity of subgame perfect equilibria, a natural question to ask is if the initial efforts can aid in the selection of a particular allocation. Our goal is to identify surplus sharing schemes conditioned on effort levels in such a way that coordinating on the efficient effort vector is selected as an equilibrium of the game.

Proportional Allocations

We start by inspecting the proportional allocation rule. Under such allocation heuristic, a player's share of the fund in percentage is determined by

$$\bar{s}_i(e_i, e_{-i}) := \frac{e_i}{\sum_{j=1}^{n} e_j}$$

and the share of the fund in monetary terms is $\bar{s}_i(\mathbf{e})F(\mathbf{e})$.[21] This strategy yields a payoff of $\bar{s}_i(\mathbf{e})F(\mathbf{e}) - e_i + 1$.

The principle of proportionality fits the definition of an equitable allocation according to Adams (1963). Inequity arises when the proportion of rewards to costs for an individual differs to the proportion of rewards to costs of other individuals in the comparison group.[22] Selten (1987) argues that such principle is a natural prediction for bargaining games with entitlements. In a symmetric linear setting without synergies in production, this redistributive strategy exactly compensates each member for her material contribution to the total fund. However, in the weakest-link game it assigns shares based on intended potential, and thus, it is worth exploring how such bargaining outcomes would alter investment decisions

[20] See Herings, Meshalkin, and Predtetchinski (2017) for a one-period recall folk theorem characterization in multilateral bargaining games.

[21] Clearly, s_i is undefined when $e_j = 0 \forall j$, however this case is immaterial because $F = 0$.

[22] In this article, inequity and inequality refer to different concepts because an equitable allocation may lead to inequality of final payoffs in the sense of Fehr and Schmidt (1999) or Bolton and Ockenfels (2000).

in the weakest-link game.

Lemma 2 Under the Proportional Allocation Rule in the bargaining game when efforts are observable:

1. If $\alpha > \frac{n}{n-1}$ the only symmetric equilibria of the game are $\mathbf{e} = \mathbf{1}$ and $\mathbf{e} = \mathbf{0}$.

2. If $\alpha \in \left(1, \frac{n}{n-1}\right]$ any symmetric vector $\mathbf{e}$ is an equilibrium.

Proof. Consider any symmetric effort vector $\mathbf{e} = (e, ..., e)$ where $0 < e \leq 1$ from which we obtain that $F(\mathbf{e}) = \alpha ne$ and $\bar{s}_i(\mathbf{e}) = 1/n$. The resulting payoff is given by $\Pi(\mathbf{e}) = \alpha e - e + 1$. We will now prove that there exists $\epsilon > 0$ such that the resulting payoff for player i from choosing $e+\epsilon$ is greater than $\Pi(\mathbf{e})$. Denote by $\bar{s}_i(e+\epsilon, \mathbf{e})$ the percentage share received from deviating which is given by

$$\bar{s}_i(e+\epsilon, \mathbf{e}) = \frac{e+\epsilon}{\sum_{j=1}^{n} e_j + \epsilon} \quad .$$

Notice that the total fund does not change because the minimum is still e. As such, the payoff from deviating is given by

$$\Pi(e+\epsilon, \mathbf{e}) = \left(\frac{e+\epsilon}{\sum_{j=1}^{n} e_j + \epsilon}\right) \alpha ne - (e+\epsilon) + 1 \quad .$$

We compute the difference in payoffs and show that

$$\begin{aligned}
\Pi(e+\epsilon, \mathbf{e}) - \Pi(\mathbf{e}) &> 0 \iff \\
\alpha e \left[\frac{n(e+\epsilon)}{ne+\epsilon} - 1\right] - \epsilon &> 0 \iff \\
\alpha e \left[\frac{(n-1)\epsilon}{ne+\epsilon}\right] &> \epsilon \iff \\
e\left[\alpha(n-1) - n\right] &> \epsilon \; .
\end{aligned}$$

From the last inequality we conclude that there exists a profitable positive deviation of size ϵ if and only if $\alpha(n-1)-n>0 \iff \alpha > \frac{n}{n-1}$. Note that at $\mathbf{e}=\mathbf{1}$ there is no possibility to increase effort, hence there is no positive profitable deviation in that case.

We now proceed to show that there is no negative profitable deviation from any symmetric vector of efforts. Consider the payoffs of decreasing by ϵ one's effort. These are given by

$$\Pi(e-\epsilon,\mathbf{e}) = \bar{s}(e-\epsilon,\mathbf{e})F(e-\epsilon,\mathbf{e}) - (e-\epsilon) + 1$$

and note that $\Pi(e-\epsilon,\mathbf{e}) < \bar{s}(\mathbf{e})F(e-\epsilon,\mathbf{e}) - (e-\epsilon)+1$ because $\bar{s}(\mathbf{e}) = \frac{1}{n} > \bar{s}(e-\epsilon,\mathbf{e})$. Hence, we have that

$$\Pi(\mathbf{e}) - \Pi(e-\epsilon,\mathbf{e}) > \Pi(\mathbf{e}) - \left[\bar{s}(\mathbf{e})F(e-\epsilon,\mathbf{e}) - (e-\epsilon)+1\right] \ .$$

We now show that

$$\begin{aligned}
\Pi(\mathbf{e}) - \left[\bar{s}(\mathbf{e})F(e-\epsilon,\mathbf{e}) - (e-\epsilon)+1\right] &> 0 \iff \\
\bar{s}(\mathbf{e})\left[F(\mathbf{e}) - F(e-\epsilon,\mathbf{e})\right] - \epsilon &> 0 \iff \\
\frac{1}{n}\left[\alpha n \epsilon\right] - \epsilon &> 0 \iff \\
\epsilon(\alpha - 1) &> 0
\end{aligned}$$

and it follows that $\Pi(\mathbf{e}) - \Pi(e-\epsilon,\mathbf{e}) > 0$ for all ϵ. ■

Remark 2 Under proportional strategies, there exist cases in which lower contributors may obtain higher payoffs despite receiving lower shares.

Exclude the Lowest and Include the Highest

The complementarities also introduce an additional asymmetry between rewards and punishments, which is not present under substitutes as in Baranski (2016, 2018). Allocating a greater share of the surplus to higher than minimal contributors implies rewarding intended potential rather than actual material contributions, as any excess beyond minimum is purely wasteful. Here, a minimal contributor stands out as one whose behavior had actual material costs to everyone else.

One of the most salient characteristics of the bargaining environment is that only q votes are needed for approval, and as multiple experiments have shown, minimum winning coalitions are often formed by excluding redundant members from the allocation. In fact, in experiments with an exogenous fund (Fréchette, Kagel, Morelli 2005a,b,c), such allocations are modal. Thus, one may conjecture that efforts can be used as a cue for whom to exclude or include in the coalition. We propose the following simple heuristic in which only the highest q contributors are offered a share of the fund, a rule that we label as "exclude the lowest, include the highest" (ELIH). This heuristic will only be meaningful when the voting requirement is less than unanimity ($q < n$) which we will assume here (our experiments implement a majority rule $q = \frac{n+1}{2}$).

Under ELIH bargaining strategies a minimum winning coalition is formed and members of the coalition split the fund in equal parts (each share is equal to $1/q$). The $n-q$ members exerting the lowest efforts are excluded from the coalition with certainty and the q members exerting the highest efforts share the surplus. We presume that using this strategy might be more salient when all members have different investments and less likely to take place if all members had the same investment.

The experiments by Fehr and Gächter (2000, 2002) provide strong evidence for the effectiveness of ex post punishment for attaining highly efficient outcomes in a linear public goods game. Ex post bargaining can serve such purpose in our setting and ELIH strategies embody the notion of punishment to low contributors and rewards to higher contributors.

Formally, let r_q be the q^{th} order statistic of the list $\{e_1, ..., e_n\}$. We must specify a tie-breaking rule for entering the winning coalition whenever more than q members are at or above r_q. For this purpose, let $E = \{i | e_i > r_q\}$ and $\underline{E} = \{i | e_i \geq r_q\}$ where $|E|$ and $|\underline{E}|$ represent the number of players in each set. We denote by s_i^{ELIH} the share received from the fund with probability θ_i. An allocation under ELIH is defined by

$$s_i^{\mathrm{ELIH}} := \begin{cases} 1/q & \text{with probability} \quad \theta_i \\ 0 & \text{with probability} \quad 1-\theta_i \end{cases}$$

where

$$\theta_i := \begin{cases} 0 & \text{if} \quad e_i < r_q \\ \frac{q-|E|}{|\underline{E}|-|E|} & \text{if} \quad e_i = r_q \\ 1 & \text{if} \quad e_i > r_q \end{cases} .$$

Lemma 3 Under ELIH bargaining strategies, the only equilibria of the game are $\mathbf{e} = \mathbf{1}$ and $\mathbf{e} = \mathbf{0}$.

Proof. Consider any symmetric vector $\mathbf{e}$ where $e \in (0, 1)$ so that profits are given by $\Pi(\mathbf{e}) = \theta_i s_i^{\mathrm{ELIH}} \alpha n e - e + 1 = \alpha e - e + 1$. We now show that there exists $\epsilon > 0$ such that exerting $e + \epsilon$ yields a higher payoff. Notice that such player is invited with certainty to a coalition of q players. Thus she receives $1/q$ of the surplus. This yields

$$\Pi(e+\epsilon, \mathbf{e}) = \frac{\alpha n e}{q} - e - \epsilon + 1$$

and clearly

$$\Pi(e+\epsilon, \mathbf{e}) - \Pi(\mathbf{e}) = \alpha e \left(\frac{n}{q} - 1\right) - \epsilon > 0$$

for some ϵ.

A player that deviates downward from a symmetric effort choice is excluded with certainty thus receiving

$$\Pi(e+\epsilon, \mathbf{e}) = -e + \epsilon + 1$$

which is strictly smaller than $\Pi(\mathbf{e})$. At $\mathbf{e} = \mathbf{0}$ it is straightforward to verify there is no profitable deviation.

Now consider any asymmetric vector $\mathbf{e}$ such that $e_{\min} > 0$. If there exists i such that

$e_i < r_q$, it is easy to show that member i has an incentive to choose 0, since being below r_q only generates an individual cost and no benefits. If there exists i such that $e_i > r_q$ then player i would benefit from choosing $e_i - \epsilon > r_q$ because she still receives $1/q$ of the fund with certainty and reduces her individual cost without affecting the total fund. If there does not exist i such $e_i < r_q$ or $e_i > r_q$ then it means $e_i = e_j \; \forall i, j$ which is the symmetric case discussed previously. Finally, if $e_{\min} = 0$, then all other players are better off by choosing 0. Thus, there are no asymmetric equilibria. ■

One may also consider a proportional split within the MWC. This would generate the same predictions because it reinforces the value of positive deviations from any interior symmetric effort choice, while negative deviations remain equally unprofitable.

Remark 3 If one considers a proportional redistribution within the MWC of the highest investors the results of ELIH remain.

Unobservable Efforts

To purposefully abide by ELIH and Proportional strategies one must know others' efforts at the proposal stage. Here we show that without observability, such strategies do not refine the set of equilibria. Let $\mathbf{e}$ be any symmetric vector of efforts. If players in the bargaining subgame abide by ELIH or Proportional, they expect to receive $1/n$. Any upward deviation will not be receive a larger amount, thus there is no incentive to increase effort.

Other Strategies

One can also conceive of alternative bargaining strategies which would be more in accordance with opportunistic behavior. For example, a proposer might be willing to exclude the highest and include the lowest into a winning coalition. It is straightforward to show that the unique equilibrium resulting from these strategies will be $\mathbf{e} = \mathbf{0}$.

Strategies like the equal split among all partners (regardless of effort choices) or randomly chosen partners in a minimum winning coalition both yield an ex ante value of the bargaining game equal to the average total fund, thus leading to no refinement of the equilibrium set of effort provision.

Potentially, players may hold a strictly egalitarian view in which everyone is equally deserving in society, regardless of effort choice. According to this redistribution ideal, the total fund should be split in such a way that wealth is equalized (or differences are minimized) among all members. One can show that any symmetric vector of efforts is an equilibrium and that no asymmetric equilibria exist (see Online Appendix A).

V. Experimental Design

We conducted four sessions per bargaining treatment, with and without observable investments, with fifteen subjects in each session. Three sessions of a control treatment without bargaining were conducted for comparison with previous weakest-link experiments. Subjects participated in only one treatment.

Within each session, subjects were matched in groups of five for one period (also called game). A period in the bargaining treatments corresponds to an investment stage and a bargaining stage (in the control treatment a period is only composed of an investment stage). Subjects were randomly rematched each of the ten periods of play and compensated for one randomly chosen period. At the end of each game, subjects were informed of their group members' investments, shares of the total fund, and resulting payoffs. Thus, the interperiod information structure is constant across treatments.[23]

Each game, subjects were endowed with 60 tokens (10 tokens equal 1 euro) and could invest any amount up to their endowment. Here we departed from the standard weakest-link experimental design in which subjects typically choose an effort level out of a few choices (most studies restrict choice sets to only seven actions). Given that we do not find any

[23] Brandts and Cooper (2006b) report that full observability of every subject's payoff and choice after each period may enhance the effectiveness of bonuses in achieving efficient coordination in the weakest-link game.

difference in behavior between our benchmark (no bargaining treatment) and previously reported experimental results, we do not believe that our design choice could be altering behavior in a systematic way. If anything, an enlarged choice set might reduce the chances of coordination on any particular level of effort.

The productivity parameter (α) equals 2 which means that the lowest investment would be doubled and then multiplied times five (the number of members in the group) in order to determine the total fund. This was explicitly told to subjects, and was deliberately designed to match the instructions of the linear production technology experiments in Baranski (2018).

In the bargaining stage we implemented a partial strategy method for proposals, each subject entered a division of the fund but only one was chosen for voting. A simple majority rule was in place requiring three out of five votes for approval ($q = 3$). Subjects were informed that they could bargain until an agreement was reached and there was no discounting ($\delta = 1$). However, it was specified that the experimenter could move a group unto the next period in case of excessive duration in reaching an agreement in order to meet the scheduled time for the experiment.[24] Sessions lasted about 90 minutes.

Experiments were conducted at the BEELab of Maastricht University between March and September 2017. Subjects were recruited via ORSEE (Greiner 2007) and a 6 euro show up fee was offered. A randomly selected period was chosen for payment and payments were done in private by the experimenter. Participants who had previous experience in Baron and Ferejohn bargaining experiments and the weakest-link game experiment according to our database were excluded from participating.

In each session, subjects were given instructions and a comprehension quiz which was later checked. The answers to the quiz were also read aloud accompanied by a verbal explanation. A guided dry run was conducted before each session so that subjects were completely familiarized with the interface. Table 1 contains information about the treatments, number

[24] In such cases, subjects would lose their initial investment and earn whatever they kept in their private accounts. The highest round of approval was round 9, and the experimenter never forced a group to the next game.

of sessions, and number of subjects.

Table 1: Treatments and Sessions

Treatment	**Session #**	**Subjects per Session**	**# of Subjects**
Observable Effort	1-4	15	60
Unobservable Effort	5-8	15	60
No Bargaining	9-11	15	45
Exogenous Component	12-15	10-15	55
Private Shares	16-19	15	60
Linear Technology (Baranski 2018)	20-25	10-15	85

After seeing our results from the main experiments, we conducted two additional treatments to answer some open questions. In the *Exogenous Component* treatment, subjects faced the same setting as in observable effort with the difference that groups possessed a initial account equal to 150 tokens regardless of effort choices. This was done to mitigate the risk of insolvency to cover aggregate costs and, under ELIH and Proportional strategies, only full effort is sustained in equilibrium.

Our theoretical characterizations assumed a purely selfish utility function, thus, we did not resort to other-regarding preferences to justify the selection of equitable allocations (ELIH or Proportional) nor to explain voting behavior. Hence, we devised a treatment (labeled *Private Shares*) where players would only see their own share at the voting stage. This way, interpersonal comparisons would be almost impossible to make and differences in average investments compared to the main treatment could then be attributed to the role of other-regarding preferences at the voting stage.

Finally, we relate our results to the linear production technology by comparing to the experimental results of Baranski (2018).[25] Our main hypothesis is that the weakest-link production technology will reduce the appeal of redistribution schemes proportional to investments, and instead, low contributing members will be punished more harshly through exclusion from the allocation. Intuitively, low investors create a material harm by destroying

[25] These experiments were also conducted at Maastricht Univeristy and followed almost identical instructions, the only differences being that investments were added and multiplied times two, subjects' initial endowments were 50 tokens instead of 60, and the show up fee was 5 euros instead of 6. The experimental software interface was identical.

part of the potential surplus when synergies are present, but not in the linear case. Thus, the negative externality imposed by low contributing members may exacerbate players incentives to form minimum winning coalitions, using investments as cue for whom to invite as specified in the ELIH strategies.

VI. Experimental Results of the Main Treatments

We first present the results on investments and efficiency in each treatment. We then investigate bargaining strategies, focusing on the incentives that arise for subjects to invest.

VI.a Investments

Average investments start at 33 tokens out of 60 (55 percent of endowment) with no significant difference between treatments as depicted in Panel A of Figure 1.[26] The fact that all treatments start at the same level reflects that there is no anticipation of the bargaining or observability effect. Average investments diverge quite rapidly. According to Mann Whitney two-sided tests we can reject the hypothesis that investments are equal in the observable and unobservable treatments (p-value=0.028) and in the observable and no bargaining treatments (p-value=0.057), but not between the unobservable and no bargaining treatments (p-value=1).

To further analyze and compare investment behavior we conducted a linear regression of investments on a period trend variable, treatment and session dummy variables, and their interactions with the period variable. The results are reported in Table 6 in the Appendix. In the observable effort treatment average investments rise on average by 1 token each period to nearly 41 tokens. Our results show that there are session trend differences: the first two sessions have an upward trend, while in sessions three and four we cannot reject

[26] Table 7 in Appendix A presents the coefficients of a linear regression of period one investments on treatment dummies. Regardless of whether session fixed effects are included or not, the treatment coefficients are not significant. The results are confirmed by two-sided Mann Whitney tests using session averages as units of observation.

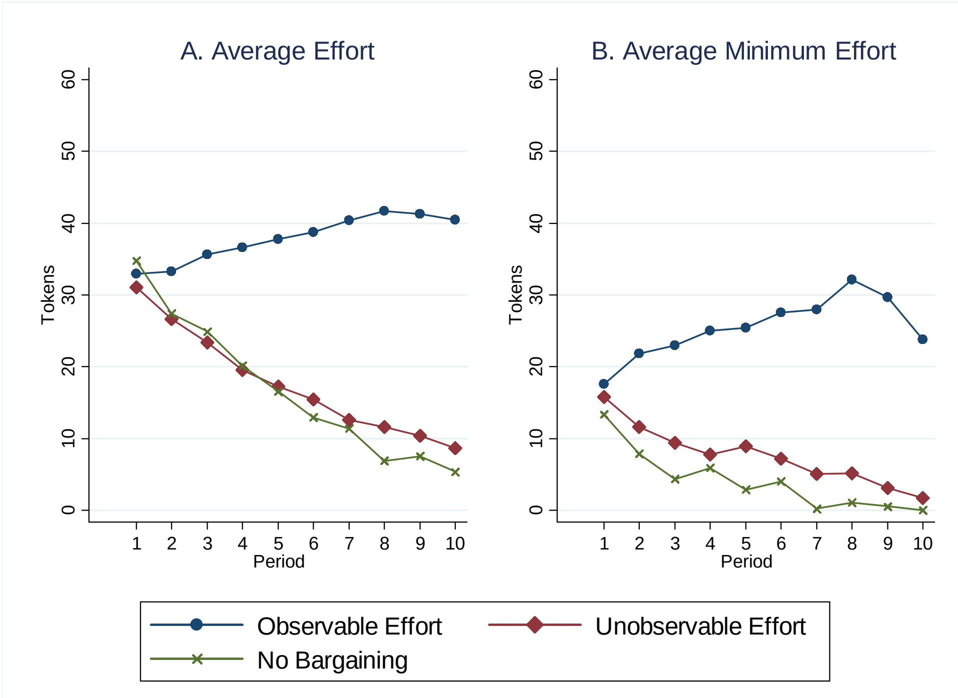

Figure 1: Investments

the hypothesis that there is no change in average investments over periods.[27] Investments decrease on average by 3 tokens each period in the unobservable effort treatment, and by 3.5 in the control treatment without bargaining. In these two treatments, the unravelling of investments is quite homogeneous across sessions as we do not observe significant differences in the trend and session interactions.

Panel B in Figure 1 shows the evolution of the minimum investment. Notice that for the observable effort treatment the maximum average fund is reached in period 8 and starts to fall thereafter. This is mainly driven by the fourth session in which all bargaining groups met with one member that did not invest in the last period.

In the bargaining observable treatment 40 is the modal choice, with almost 80 percent of investments being between 30 and 50 tokens. Even though the unobservable effort and control treatments have a similar pattern for average investments over time, the control treatment shows a larger dispersion of investment choices with a modal choice of 0, while

[27] Wald tests for $Period \times Session\ 3 = 0$ and $Period \times Session\ 4 = 0$ yield p-values> 0.1.

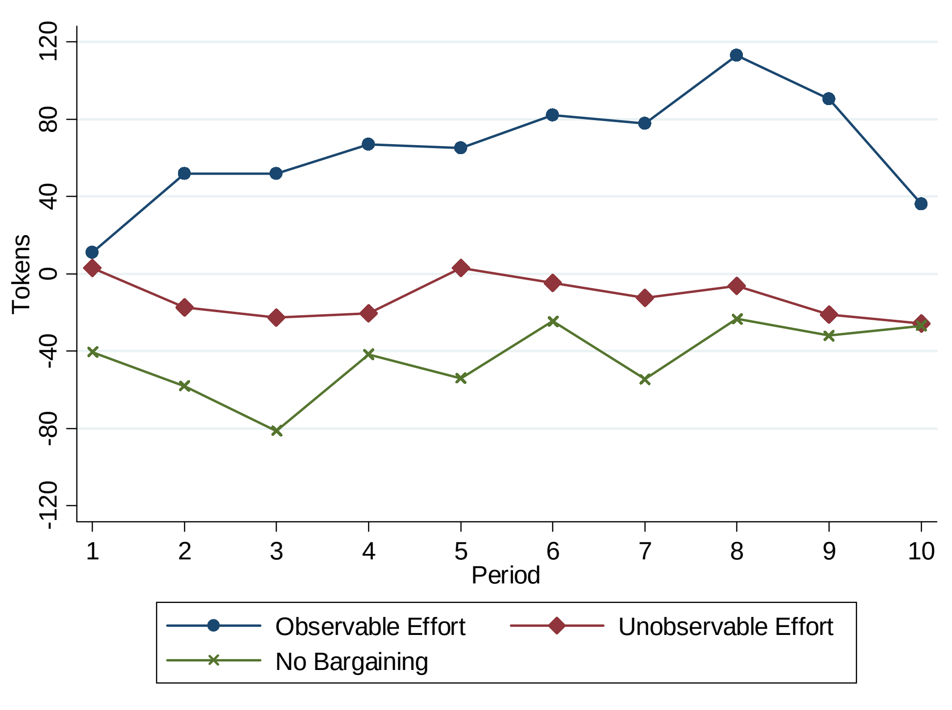

Figure 2: Net Efficiency Gain: Production minus Costs

the modal choice is 10 in the unobservable effort treatment. Histograms for the frequency of investment levels by treatment can be found in Figure 5 (Appendix A).

We are interested in the deleterious effect that uncoordinated actions can have in an economy so we now turn to inspect the total surplus minus the sum of investments in a group.

In Figure 2 a positive value indicates an aggregate economic gain because the value of production exceeds the cost of inputs. The average net surplus for the observable effort treatment increases by almost 70 percent between the first and second half of the experiment. This is driven by two effects: an increase in the average minimum investment and an increase in coordination as measured by a lower dispersion of investments.[28] In the unobservable effort treatment, both the total surplus and the variance in investments fall between the first and

[28] We conducted Levene's test for equality of variances between investments in the first and second half and obtained a p-value=0.051, thus rejecting the null hypothesis that the variances are equal. The test statistic was computed using the group median. Since Levene's test is valid under non-normality we performed a normality test for the distribution of investments which yields a p-value<0.001 for the skewness and 0.003 for kurtosis. Thus, we reject the null hypothesis that investments are normally distributed.

second half.[29] The increase in coordination exactly counteracts the fall in the average total fund which explains why the net surplus does not change significantly between the first and second half of the experiment. In the treatment without bargaining there is also an increase in coordination after the first half[30] but the variance in investments is always higher compared to the unobservable effort treatment.

Conclusion 1 Ex post bargaining increases efficiency in the weakest-link game. When the group can perfectly monitor its members by observing individual investment decisions, the largest efficiency levels are attained.

We now turn to analyze bargaining outcomes in order to understand the pronounced difference in investments between treatments.

VI.b Bargaining Outcomes

In this section we are mainly concerned with the relationship between initial investments and the distribution of the surplus. As a raw measure of profitability, we calculated the proportion of investments resulting in a positive return (i.e. those in which the share received is greater than the invested amount) as displayed in Table 2. This happened for 63 percent of investments in the bargaining treatment with observability and 39 percent of the time with unobservable investments. Positive returns occur only 19 percent of the time in the control treatment.[31]

A second measure of profitability that we explored consisted of the relative return defined as the ratio of share to investment. Conditional on making a positive investment, the average return is 1.28 in the observable effort treatment, 0.97 in the unobservable treatment, and

[29] We reject the null hypothesis of Levene's test that the variances of the first and second half of the experiment are equal (p-value<0.001).

[30] Idem.

[31] The differences are significant between treatments. We regressed a dummy variable equal to one when a subject makes a positive return on treatment dummies and clustered standard errors at the session level. The estimated coefficient for the unobservable bargaining treatment dummy was -0.297 (p-value=0.01), -0.544 for the control (p-value<0.001), and a constant of 0.606 (p-value<0.001). The observable bargaining treatment was the base level.

Table 2: Percentage of Investments Yielding a Positive Return by Treatment

	Games 1-5	Games 6-10
Observable Effort	62.5	62.5
Unobservable Effort	44.8	33.6
No Bargaining	25.4	10.9

An investment is counted as yielding a positive return if the share received is strictly greater than the investment.

0.51 in the control. Both measures of profitability are largely consistent with the pattern of investments in Figure 1.

No Evidence for Stationary Subgame Perfect Equilibrium Strategies. — In the theoretical section we explained that the stationary strategies do not refine the set of equilibria in the investment stage. As expected, we do not find strong evidence in favor of such strategies in either bargaining treatment. For example, the SSPE predicts that proposers keep 60 percent of the fund while in the experiments the mean proposer's share is close to 30 percent in both bargaining treatments (the treatment difference is not significant).[32]

Concerning the overall allocation of the fund, we first broadly categorized proposals as three, four, and five-way splits depending on how many members received a meaningful share of the common profits.[33] Although for our particular purposes such proposal classifications are not essential to studying history-dependent bargaining strategies, they do reveal a divergence from previous experimental findings of bargaining over an exogenous fund. Three-way splits represent 47 and 35 percent in the observable and unobservable treatments. This proportion is far below the levels observed in BF experiments with an exogenous fund (above 80 percent in Fréchette, Kagel, and Morelli (2005a)). Five-way splits, which are virtually inex-

[32] We regressed the proposers' shares as a percentage of the total fund on treatment dummies with standard errors clustered at the session level. The coefficient for the unobservable bargaining dummy is not significant (p-value=0.934).

[33] A member receiving more than 5 percent of the fund is counted as included. For example, the allocation (30,30,30,5,5) if the total fund is 100 tokens counts as three-way split (MWC) while (30,30,25,10,5) is a four-way split.

istent in the previous experiments, account for almost 38 percent of the approved proposals in both the observable and unobservable effort treatments.

Investment-dependent Bargaining Strategies. — We now turn to examine *who gets what* in order to understand the divergence in investment patterns. Figure 3 presents a scatter plot in which each point represents an investment and share pair (in tokens) for a subject in a given period of play. The dotted line is the identity relation denoting a player that exactly recovers her investment; observations above it represent a net gain. Investments are classified into two groups: those below the group's median (denoted by a circle) and those at or above the median (denoted by a triangle). Panel A of Figure 3 shows that 59 percent of below-median investments (circles) lie in the horizontal axis where the share received is equal to zero while this is only true for 11 percent of higher contributions. Moreover, 85 percent of investments which are greater than or equal to the group's median yield a positive return while only 27 percent of below-median investments (triangles) do so.[34] This pattern contrasts with what we observe in Panel B for the unobservable treatment where below-median investments face a 66 percent chance of making a positive return and at- or above-median investments only a 35 percent chance.[35] Probit models reported in Table 8 of the Appendix robustly confirm the statistical significance of these results and an equivalent result holds when pooling all periods of play.

As expected, we find a significant positive correlation ($\rho = 0.502$, p-value<0.001) between the share received as a proportion of the total fund (s_i/F) and the member's investment as a proportion of the sum of investments ($e_i/\sum e_j$) in the observable effort treatment. The correlation coefficient for the unobservable effort treatment is 0.073 and not significantly different than zero (p-value>0.1), more in line with a random choice of coalition partners.[36] This provides further evidence in favor of contribution-dependent bargaining strategies.

[34] If we include those who break even the percentage of above-median investors who make a non-negative return remains at 85 while the below-median investors making a return slightly increases to 29 percent.

[35] The analysis in this paragraph and the data in Figure 3 excludes observations from groups in which there was no bargaining due to at least one member investing zero.

[36] Recall that strategies based on a random choice of coalition partners do not refine the set of equilibrium efforts.

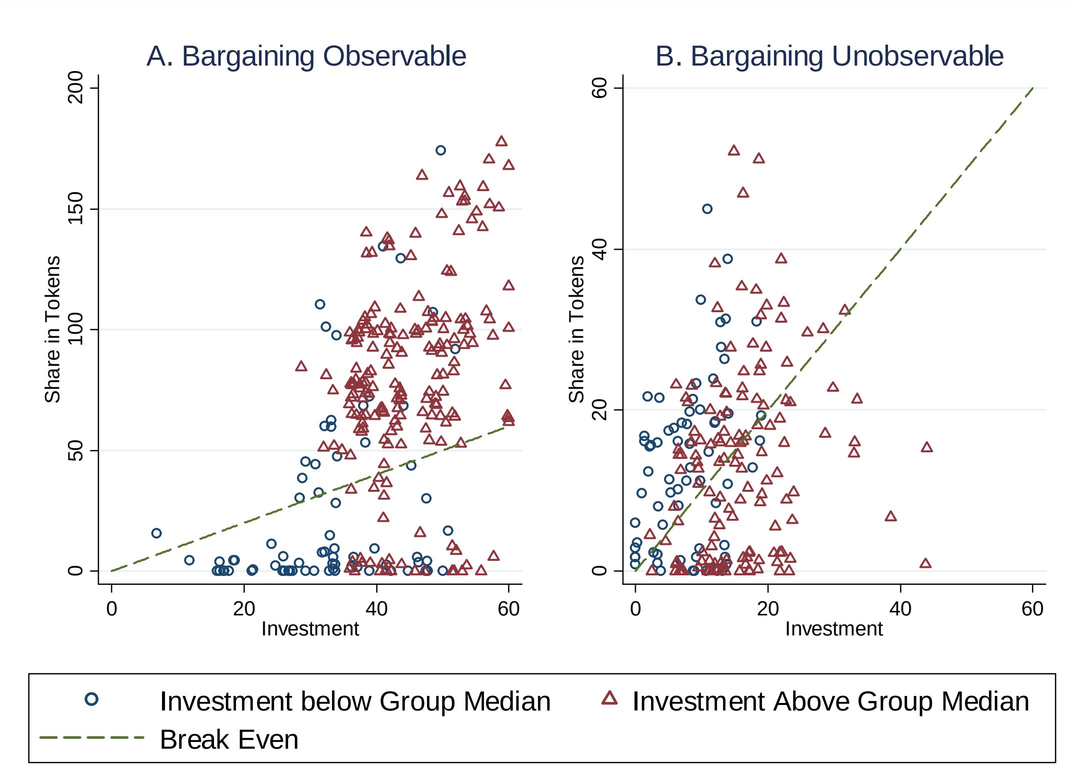

Figure 3: Investments and Shares in Approved Allocations of Games 6-10

In Section 4 we discussed potential investment-dependent bargaining strategies: the proportional redistribution rule and the "exclude the lowest include the highest" heuristic (ELIH). Both of these can only be effectively implemented in the observable effort treatment. We start by examining whether or not subjects abide by the proportionality standard. In order to measure how close a given proposal is to the proportional redistribution strategy we compute a proportionality index (PI) as follows:

$$PI := \sqrt{\sum_{i=1}^{5} \left(\frac{s_i}{F} - \frac{e_i}{\sum_{j=1}^{5} e_j} \right)^2} \tag{1}$$

which yields the Euclidean distance of an allocation (where shares are measured as a percentage of the fund) to the proportional allocation. When $PI = 0$, a proposal exactly follows the proportional redistribution rule. To give the reader an idea, if all members contribute the same amount and an equal three-way split is implemented the $PI = 0.365$ and a four-way equal split yields $PI = 0.224$.

We counted how often each subject made a proposal which was close to a proportional scheme with two threshold measures: $PI < 0.05$ and $PI < 0.1$. This analysis includes all proposals made in the first round of bargaining of a given period, including those that were not selected for voting (i.e. one observation per subject per period conditional on a positive fund) and the results are presented in the first two columns of Table 3.[37] Our data show that 29 out of 60 subjects redistribute proportionally (for $PI < 0.05$) in at least one game and 31 subjects never do so. Approximately 15 percent of approved allocations are close to the proportionality standard.

Table 3: Frequency of Investment-Dependent Bargaining Strategies in the Observable Effort Treatment[1].

# of times used by a given subject[2]	Proportional		ELIH Theory		ELIH Retrieve		Opportunistic
	Strict	Weak	Strict	Weak	Strict	Weak	
Never	31	13	26	22	7	1	37
1 time	14	10	11	10	15	3	11
2 times	7	10	1	4	5	3	5
3 times	4	8	7	6	10	1	3
4 times	2	6	4	5	7	9	3
5 or more times	2	13	11	13	16	43	1
Accepted Proposals (%)	14.3	26.8	30.4	33.9	41.1	70.5	8

[1] A detailed description of the bargaining strategies can be found in body of the article.
[2] We only consider the first proposal submitted by a subject in each bargaining game. There are a total of 60 subjects.

We now turn to analyze if there is evidence for ELIH strategies being used by subjects in the experiment. The two columns under the header *ELIH Theory* in Table 3 refer to proposals that satisfy the characterization presented in the theory section. The strict version requires the proposal to be a minimum winning coalition and that the division of the fund

[37] In the experiment we implemented the strategy method at the proposal stage reason for which we have data on all proposals, even those that were not selected to be voted on.

within the minimum winning coalition should be approximately an equal split.[38] In the weak version, the allocation need not be a minimum winning coalition, but only members who contribute at or above the median are eligible partners (to allow for ties). For example, this measure includes an equal split in which all members invested the same amount. In total, 34 subjects implemented the strict ELIH at least once, and 15 subjects did so 4 or more times during the experiment. An important observation is that ELIH strict proposals were never rejected. While the theoretical ELIH strategies are indeed used by subjects, they are not an overwhelming majority of the approved proposals with the weak version representing only 33.9 percent of all allocations.

We inspected alternative characterizations of bargaining strategies in order to identify a more accurate description of subjects' behavior. Under *ELIH Retrieve* strategies, a member is counted as included in the coalition if she obtains a share greater than or equal to her investment. Importantly, only those investing at or above the median are eligible under the strict measure, which represents about 40 percent of approved proposals. Under the weak measure, players contributing below the median may also be invited to the coalition, however the allocation may not exclude any member contributing at or above the median if players below the median are to be invited.[39] In other words, this latter measure defines a priority rule based on the ranking of investments for assigning shares to coalition partners. Noticeably, 70 percent of approved allocations fit this description with 43 subjects submitting such proposals five or more times during the experiment and only one subject never doing so.

We find little evidence for opportunistic behavior. Our measure of opportunism is a minimum winning coalition in which the three members with the lowest efforts receive a share greater than or equal to their investments and those above the median do not. As the

[38] In the theory section such strategies specified an equal split of the fund among coalition members. In our empirical measurment we allow for wiggleroom by requiring that a partner's share be above 80% of the share resulting from an equal split among the coalition.

[39] For example if investments are (20,30,30,30,50), the allocations including players 3,4, and 5 or 2,3,4 and 5 are the only strict ELIH retrieve schemes. The previous allocations and the allocation including all players are weak. Any allocation including player one, must also include all other players to count as ELIH weak.

last column in Table 3 shows, 37 subjects never implemented them.

Conclusion 2 Investment-dependent bargaining strategies are consistent with the efficiency levels that arise in the observable effort treatment. A priority rule for distributing the total fund based on the relative ranking of efforts characterizes almost 70 percent of bargaining outcomes. Opportunistic proposals in which above-median contributors are excluded from the allocation represent only 8 percent of approved allocations.

One may argue that reported behavior can also be random and allocations spuriously fall into the analyzed categories. As a benchmark, we repeated the exercise for the unobservable effort treatment (table reported in Online Appendix B), which clearly evidences that this is not the case. 4 percent are classified as Weak ELIH Retrieve, and no approved allocation has a proportionality index below 0.05. Interestingly, almost 18 percent of approved allocations are classified as opportunistic which is quite close to what one would expect from a random choice of coalition partners.[40]

Dynamics of Investment Behavior. — The first period effort choice is on average the same across treatments, thus the incentives to invest (or not) appear to be learned from experience within the sessions. We now turn to examine dynamic behavior for which we propose a very simple model of the relationship between effort adjustment and lagged returns.

We define $\Delta C_{i,t} := C_{i,t} - C_{i,t-1}$ where $C_{i,t}$ is subject i's contribution in period t and $R_{i,t-1} := Share_{i,t-1} - C_{i,t-1}$ as the net return to investment in tokens in the previous period. Let $\delta_{i,t-1}^{\text{Below Median}}$ be a dummy variable that takes the value 1 when subject i's investment was below her group's median investment in the previous period $(t-1)$ and let $\delta_{i,t-1}^{\text{Minimum}} = 1$

[40] Consider a vector of efforts such that there are exactly three members at or below the median. Then, the probability of one of those members proposing is 60 percent and the probability the she randomly forms a coalition with the two lowest members is 25 percent, leading to a total probability of 15 percent for an opportunistic allocation to arise by chance.

when her investment was the minimum one. The econometric linear model we estimate is

$$\Delta C_{i,t} = \beta_0 + \beta_1 R_{i,t-1} + \beta_2 \delta_{i,t-1}^{\text{Below Median}} + \beta_3 R_{i,t-1} \times \delta_{i,t-1}^{\text{Below Median}} + \epsilon_{i,t} \tag{2}$$

where $\epsilon_{i,t}$ is the error term.[41] For the observable effort we also estimated

$$\Delta C_{i,t} = \beta_0 + \beta_1 R_{i,t-1} + \beta_2 \delta_{i,t-1}^{\text{Minimum}} + \beta_3 R_{i,t-1} \times \delta_{i,t-1}^{\text{Minimum}} + \epsilon_{i,t} \tag{3}$$

for robustness. Table 4 presents the estimated coefficients for the models specified in equation (2) and (3). In columns (1),(3) and (5) we introduced period dummies but these did not alter the qualitative results of our analysis.

Table 4: OLS Regression for Investment Adjustment based on Previous Game Performance.

	Observable Effort				Unobservable Effort	
	(1)	(2)	(3)	(4)	(5)	(6)
Return	0.0339*	0.0295*	0.0388**	0.0337*	0.193***	0.192***
	(0.0136)	(0.0124)	(0.0139)	(0.0130)	(0.0327)	(0.0319)
$\delta^{BelowMedian}$	8.712***	8.654***			5.384***	5.402***
	(1.217)	(1.205)			(0.944)	(0.928)
Return $\times \delta^{BelowMedian}$	-0.100**	-0.0915**			-0.173**	-0.181**
	(0.0334)	(0.0309)			(0.0570)	(0.0534)
$\delta^{Minimum}$			9.397***	9.091***		
			(1.251)	(1.232)		
Return $\times \delta^{Minimum}$			-0.134***	-0.130***		
			(0.0303)	(0.0295)		
Constant	-2.148	-2.201***	-1.372	-1.954***	-5.523***	-3.501***
	(1.321)	(0.589)	(1.258)	(0.526)	(1.413)	(0.420)
Num. Obs.	540	540	540	540	540	540
R^2	0.174	0.162	0.196	0.181	0.189	0.175
F-statistic	6.056	17.78	6.480	19.54	10.58	27.37

***,**,* denote significance at 0.1%, 1%, and 5% respectively. Standard errors are clustered at the subject level and reported in parentheses below coefficient values.

[41] In the online Appendix we also present the estimation results for random and fixed effects specifications which result from adding the subject specific effect α_i to the equations above. The qualitative results are the same.

In the observable effort treatment one can see that contributing below the median in the previous period has a strong positive impact in next period's investment adjustment decision. The fact that below-median investors are typically excluded from the allocation (or do not make a positive return) certainly sparks subjects' willingness to invest. The negative interaction coefficient ($\hat{\beta}_3$) reveals that when a player's investment is below his group's median, making a negative profit creates an incentive to invest more in the next round (the overall effect of the return is negative in that case ($\hat{\beta}_1 + \hat{\beta}_3 = -0.066$, based on column 1 estimates). Similarly, making a loss conditional on being a below-median contributor correlates with an increase in next period's investment. Our estimations also show that subjects who invest above the group median in the previous game are less sensitive to their returns when adjusting their investment decisions. In fact, if a player makes a net return of 10 tokens and her contribution was above the median in the previous period, we cannot reject the hypothesis that she will invest the same amount as before.[42] A similar analysis to the one presented in this paragraph holds for a model in which we replace the regressor of being below the median by being equal to the minimum investment in the previous period (see columns (3) and (4)).

Notice that when efforts are unobservable the qualitative results hold since investments are positively correlated with lagged returns, but the response is stronger (we reject the hypothesis that $\hat{\beta}_1^{\text{obs}} = \hat{\beta}_1^{\text{unobs}}$, p-value<0.001), and subjects increase their investments when they were below the median in the previous period less drastically (p-value<0.05). The fact that even when making losses previously $\hat{\beta}_2^{\text{unobs}}$ is positive can be indicative of a taste for efficiency. We find no significant differences between $\hat{\beta}_3$ in each treatment (p-value>0.1). Overall, given that negative returns prevail in this treatment, our results are indicative of a stronger downward adjustment when facing losses compared to the upward adjustment in efforts for an equivalent positive return.

In the appendix we report the results for an ordered probit specification for the ob-

[42] We conducted a test for $10\hat{\beta}_1 + \hat{\beta}_0 = 0$ and obtained a p-value=0.173.

servable effort treatment with three outcomes: decreasing, maintaining, or increasing one's investment with respect to the previous period. The independent variables were a dummy for whether a player receives a share greater than or equal to her investment in the previous period, a dummy for being below the median investment in the previous period, and an interaction term. Our estimates reveal that conditional on receiving a share greater than or equal to one's investment in the previous period, subjects whose previous contributions were below their group's median were 2.5 times more likely to increase their investments compared to those who invested at or above the group median in the previous game (55 percent and 20 percent respectively). Our model also predicts a large probability of remaining at the same investment level for those who retrieve their investments, regardless of the relative ranking of their contribution within their groups in the previous period (39 percent for those below the group median and 53 percent for the rest).

Treatment of Observable Efforts with an Exogenous Component. — Despite the fact that shares in the observable effort treatment correlate positively with investments, full contributions do not arise. Our theoretical characterization of ELIH and Proportional strategies reduce the set of equilibrium investment vectors to only full or no contributions, where the latter equilibrium is selected under the security criterion (when all players choose the strategy that maximizes their own payoff in the worst possible scenario). The exogenous component treatment was designed to eliminate the inefficient equilibrium under ELIH and proportional strategies so that one could test whether such concern was the reason why subjects were not fully investing.

We find that average investments in the exogenous component are almost 10 percent higher compared to the main treatment (see Figure 4) but the difference is not statistically significant when regressing investments on a treatment dummy, controlling for fixed session effects, and clustering standard errors at the subject level (p-value=0.237).[43] We then are able to rule out the role of the security criterion as an inhibitor of investments in the

[43] A Mann Whitney test using session level averages further confirms this result (two-sided test, p-value=0.486).

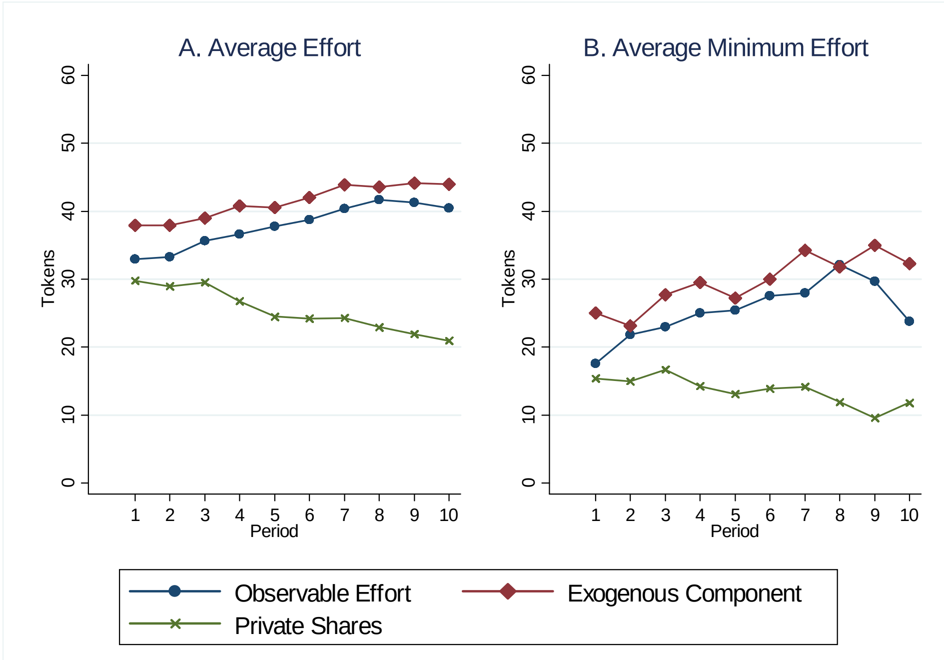

Figure 4: Average Investments in Private Shares and Exogenous Component Treatments.

bargaining treatments.

Treatment with Private Shares. — Figure 4 shows that average efforts in the private shares treatment are below those of the treatments when shares are public and efforts are observable (p-value=0.024).[44] We cannot reject the hypothesis that mean investments are equal between the private shares treatments and the treatment with unobservable efforts (one-sided Mann Whitney test p-value=0.1).[45]

Our theory assumes that ELIH or proportional strategies are selected in equilibrium not because of other-regarding concerns explicitly modelled in the utility function, but due to potential off-equilibrium punishment strategies that would make it individually unprofitable to deviate. The private shares treatment allows for the same punishment strategies that could be implemented in the observable effort treatment, because if an allocation is rejected,

[44] One-sided Mann Whitney test using session averages as the unit of observation. We pooled the data from the exogenous component and observable effort treatments to increase power. A regression of efforts on a dummy for private shares controlling for session fixed effects and clustering standard errors at the subject level yields a significant negative coeficient (p-value<0.001).

[45] When regressing investments on a treatment dummy controlling for session effects and clustering at the subject level we do not obtain a significant treatment coefficient (p-value=0.688).

the full vector of shares is reported. Thus, the only difference between treatments is if players know when voting how much others are offered. Such information difference has consequences for the distribution of resources as the proposer's share is on average 34.7 percent of the total fund which is significantly higher compared to the what proposers keep when shares are public (one-sided Mann Whitney test p-value=0.014). We also find that approved allocations are closer to the proportional standard (one-sided Mann Whitney test p-value=0.024) when shares are public. ELIH Retrieve strategies are present in only 42.7 percent of approved allocation with private shares which also significantly smaller compared to when shares are public (p-value=0.004).

As such, we cannot rule out the effect of other-regarding concerns in fostering the proposal and acceptance of allocations which positively correlate investments with shares. Instead, proposers take advantage of this information asymmetry and efficiency declines.

Linear Production Technology. — Average investments in the linear production technology treatment are close to 75 percent of endowment which are somewhat higher compared to 63 percent in the observable effort treatment (aggregating over all periods). Using sessions averages as the unit of observation, we cannot reject the null hypothesis that average investments are equal (p-value=0.609, two-sided Mann Whitney test).

We conjectured that proportionality would be more prevalent as a redistributive strategy in the linear case and find that 38.8 percent of approved proposals satisfy $PI < 0.05$ (14 percent for the weakest link case). ELIH strict strategies which entail a exclusion of below-median investors, account for only 9 percent of approved proposals (30 percent in weakest link). If we do not count the three-way equal splits in equal contribution groups ELIH strict allocations drop to 3 percent.[46] Although the results are qualitatively in the direction of our hypotheses reflecting that proportionality is more common in the linear case and ELIH in the presence of synergies, non-parametric Mann Whitney tests yield barely significant

[46] Notice that if all members invest the same amount and a three-way equal split is formed, such allocation fits both the definition of an ELIH strict and opportunistic strategy.

differences between treatments.[47]

Importantly, the ELIH Retrieve characterization also encompasses a large proportion of the allocations (slightly above 80 percent) and thus, such priority rule generally describes a vast majority of the observed bargaining behavior under both production technologies. This mode of behavior can be indicative of a broader principle that underlies equity considerations which catalyze efficiency gains.

VII. Discussion and Concluding Remarks

In many organizational structures, a coach, manager, or dictator has the discretion to assign tasks and compensations in a way that she perceives will lead to efficient outcomes. Such has been the object of study in contract theory as addressed seminally by Hölmstrom (1982) on how to provide incentives to teams. But coordination through a central authority is not the only way in which collective bodies are managed. A significant amount of firms such as business partnerships are self-governed, a process which naturally requires negotiations and agreements between those involved in the production process. Our setting can also be used to study self-managed (or autonomous) teams such as researchers on a joint project who assign authorship credit after they completed a project. Military, political, and geopolitical alliances often operate in a multilateral framework in which decision-making power is shared among members and so are the benefits that the alliance might reap. Another example may be found in democratic states: taxing and spending decisions can be modelled as a game of multilateral negotiations in which the surplus to redistribute is endogenously created (Battaglini and Coate 2007, 2008). Thus, understanding how a democratic mechanism for the redistribution of resources in an group can help achieve efficient coordination is an open question on which our main contribution lies.

[47] A one-sided Mann Whitney test using session averages as the unit of observation for the percentage of proportional allocation in the observable effort treatment being greater than the in the linear production treatment yields a p-value=0.109. Testing for the proportion of ELIH strategies being greater in the observable effort treament than in the linear production yields a p-value=0.107. For our test we pooled data from the exogenous component and observable effort treatment.

Our results, together with those of Baranski (2016, 2018), provide a rationale for the existence of participatory mechanisms in the redistribution of jointly produced profits. Productive efforts, when observable by group members, establish *behavioral property rights* which are largely respected. Despite the well-documented plurality of fairness ideals, and the fact that a non-separable production technology may exacerbate the degree of conflicting views of equity, we find that subjects implicitly coordinate on bargaining strategies which give rise to efficiency gains when synergies are present. When there are synergies in production, bargaining outcomes tend to punish more harshly undercontributors. Allocations in which the members exerting the below-median efforts are excluded are more prevalent as compared to the linear production setting in which allocations fitting the proportional standard are more common. We conjecture that in a repeated interaction setting with stable partners higher efficiency gains may be attained, but a proper experiment is certainly required.

The model explored here is simple and tractable, allows for testable theoretical predictions, and speaks to a broad body of work. By concatenating the Baron and Ferejohn (1989) model of multilateral bargaining with the weakest-link game (van Huyck, Battalio, and Beil 1990) we bring together several streams of literature including political economy, organizational behavior, public economics, coordination, and social preferences. It remains to be studied if our results are robust to alternative bargaining mechanisms as well as production technologies in order to better understand the relationship between redistributive behavior and joint production, in particular how redistribution schemes adjust in order to foster efficiency.

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Appendix A. Supporting Tables and Figures

Table 5: Bargaining Outcomes[1]

	SSPE Prediction	Observable	Unobservable
Proposals[2]			
3-way split (MWC)	100%	60.4	43.9
4-way split	0%	15.1	36.6
5-way split	0%	24.5	19.5
Average Shares[3]			
Proposer's Share	60%	29.6 (0.008)	31.1 (0.011)
Proposer's Share in MWC	60%	33.6 (0.005)	37.3 (0.008)
Voter's Share (conditional on share>5%)	20%	26.0 (0.007)	24.9 (0.007)
Voter's Share in MWC	20%	31.7 (0.007)	31.2 (0.005)
Correlations[4]			
Investments and Shares	0	0.542*	0.052
Investments and Shares (Proposers)	0	0.387*	-0.027
Investments and Shares (Voters)	0	0.553*	0.091
Timing of Approval			
Round 1	100%	71.7	70.7
Round 2	0%	18.9	19.5

[1] Outcomes are reported for accepted allocations of periods 6-10 and excluding groups in which the total fund was zero since no bargaining game is observed.
[2] Members receiving 5% or less are counted as excluded from the allocation.
[3] Standard mean errors reported in parentheses below.
[4] The correlation is between the investment as a proportion of the sum of the group's investments and the share is relative to the total fund. In a stationary equilibrium initial investments are irrelevant for determining shares, thus the model predicts zero correlation. * denotes significance at the 1 percent level. These correlations are computed conditional on bargaining taking place.

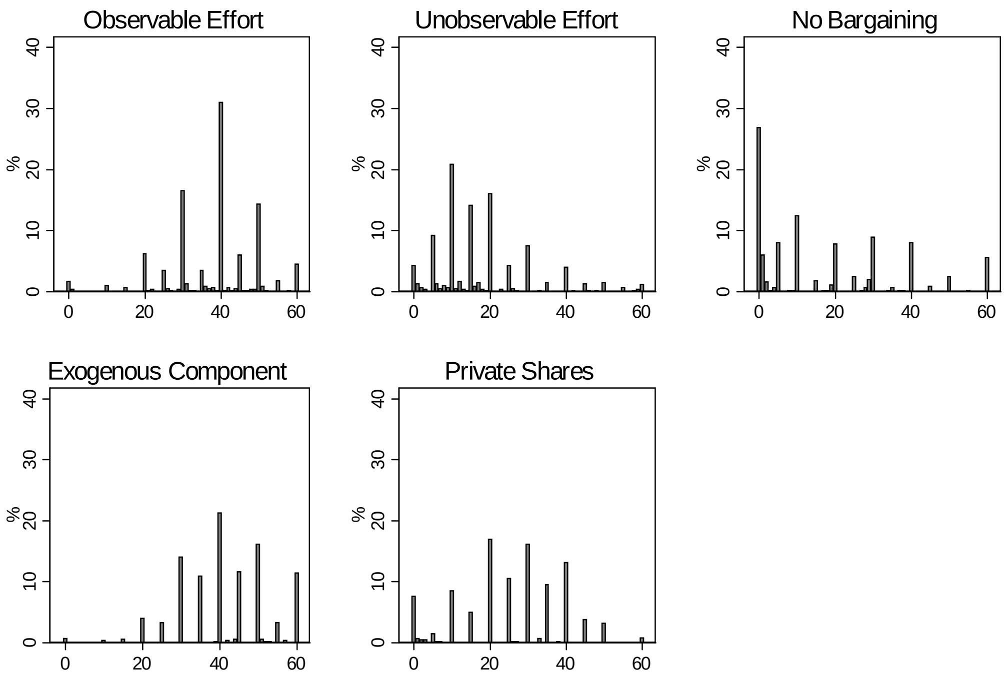

Figure 5: Distribution of Investments by Treatment in all Games.

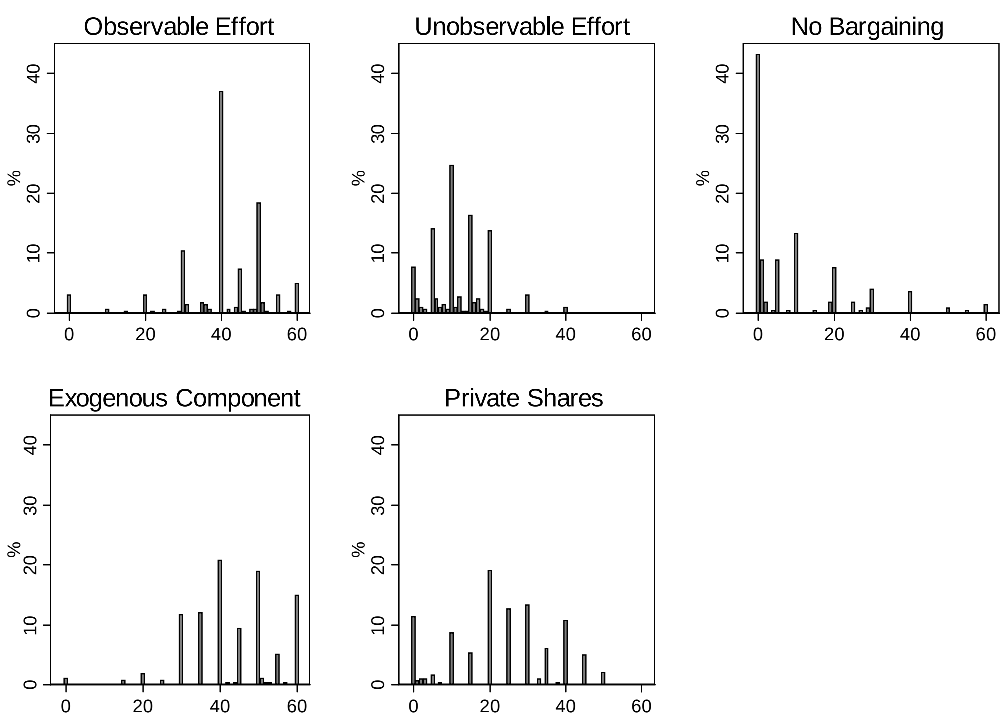

Figure 6: Distribution of Investments by Treatment in Games 6-10.

Table 6: OLS Regressions for Investment Trends [1]

	Dep. Var.: Investment	
	Coefficient	Standard Error
Constant	29.02***	(2.715)
Period	1.095***	(0.316)
Session 2	2.098	(3.532)
Session 3	5.867	(3.584)
Session 4	5.351	(4.525)
Session 2 × Period	1.189**	(0.427)
Session 3 × Period	-0.825	(0.477)
Session 4 × Period	-0.715	(0.655)
Barg. Unobs. (=1 if yes)	-6.671	(3.575)
Barg. Unobs. × Period	-3.032***	(0.410)
Session 5	13.52**	(4.786)
Session 6	7.516	(4.239)
Session 7	13.19**	(4.472)
Session 5 × Period	-0.831	(0.627)
Session 6 × Period	-0.249	(0.505)
Session 7 × Period	-0.806	(0.469)
Control (=1 if yes)	14.53**	(5.218)
Control × Period	-3.575***	(0.493)
Session 10	-6.702	(6.633)
Session 11	-21.28***	(5.412)
Session 9 × Period	-1.198	(0.632)
Session 10 × Period	-0.882	(0.729)
Num. Obs.	1650	
R^2	0.555	
F-Statistic	84.87	

***,**,* denote significance at 0.1%, 1%, and 5%. Standard errors reported in parentheses below coefficient values.

[1] Standard errors are clustered at the subject level (165 clusters in total).

Table 7: OLS Regressions for Period 1 Investments[1]

	Dep. Var. Investment in Period 1	
	Session Fixed Effects	No Fixed Effects
Unobservable Effort	-8.533	-1.883
	(5.555)	(2.864)
Control	-4.467	1.806
	(5.555)	(3.093)
Constant	30.87***	32.95***
	(3.928)	(2.025)
N	165	165
^{2}	0.113	0.00879
F-Statistic	1.972	0.718

***,**,* denote significance at 0.1%, 1%, and 5% respectively. Standard errors reported in parentheses below coefficient values.

Table 8: Probit Models for ELIH Strategies

	Dep. Var. Retrieve Investment		Dep. Var. Share≤ 5%		Dep. Var. Share= 0	
	All Games	Games 6-10	All Games	Games 6-10	All Games	Games 6-10
Below-Median Constributor (=1)	-0.943**	-1.575***	1.113***	1.399***	1.030***	1.301***
	(0.292)	(0.243)	(0.322)	(0.285)	(0.301)	(0.263)
Constant	0.439**	0.608*	-1.105***	-1.071***	-0.891***	-0.724**
	(0.158)	(0.260)	(0.225)	(0.214)	(0.210)	(0.272)
Num. Obs.	480	240	480	240	480	240
pseudo-R^2	0.085	0.214	0.132	0.197	0.110	0.162
$\chi 2$	10.40	42.19	11.92	24.11	11.72	24.48

***,**,* denote significance at 0.1%, 1%, and 5% respectively. Standard errors reported in parentheses below coefficients are clustered at the session level. Results are robust to clustering at the period level.

Table 9: Ordered Probit for Decreasing, Maintaining, or Increasing one's Contribution with respect to the Previous Period in Observable Effort Treatment.

Retrieved investmet lag (=1 if yes)	0.358**
	(0.133)
Below group median lag (=1 if yes)	1.365***
	(0.190)
Below median and Retrieved lag	-0.506*
	(0.258)
Cutpoint 1 (Maintained Contribution)	-0.139
	(0.195)
Cutpoint 2 (Increased Contribution)	1.341***
	(0.189)
Num. Obs.	540
pseudo-R^2 0.0894	
χ^2	94.16

***,**,* denote significance at 0.1%, 1%, and 5% respectively. Standard errors are clustered at the subject level and reported in parentheses below coefficient values. Period dummies not shown.