Public Goods, Teams and Institutions

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We use an experiment to study unverifiable contributions to a public good in a small team of two players with asymmetric productivity. We compare two institutions: In one, players use a simple bidding mechanism to choose a contract before investing. After having chosen ownership of the output, they contribute. In the other institution, players rely on ex-post coordination. First, they contribute and then they play a Nash demand game to split profits. In the second institution, theoretically, coordination could lead to an efficient outcome. The team could follow a convention which would allow players to make efficient equilibrium investments. Such an outcome cannot be obtained in the equilibrium of the first institution, with a predetermined contract. However, we find the opposite. Joint production is higher when ownership is determined before contributions are made.

A. Introduction

Consider two players who invest in a common good. Investments are not verifiable; hence, players can't write contracts contingent on their investments. They might be able to condition contracts on the output. We can call such a situation a prisoners' dilemma or a public goods problem. Following Coase (1937) and, more specifically, Grout (1984), contracts based solely on an ex-ante determined division of joint output may yield underinvestment.

Taking a behavioural perspective, we might hope that ex-post negotiation helps reach efficient contributions. One group of behavioural studies considers the problem of a single player (e.g., Sonnemans, Oosterbeek, and Sloof 2001; Oosterbeek, Sonnemans, and Velzen 2003; R. Sloof, Sonnemans, and Oosterbeek 2004; Ellingsen and Johannesson 2004a). Here, we consider a situation where all members of the team participate in the investment, even though their productivity can be asymmetric.

A setting where both team members can contribute is more similar to Hackett (1993), Hacket (1994), and Gantner, Güth, and Königstein (2001). Gantner, Güth, and Königstein (2001) use a linear and additive production function. They allow players to distribute profits ex-post using either an ultimatum game or a Nash demand game. The linear and additive production function might yield corner solutions, which is indeed what they find in their experiment. Here, to avoid corner solutions, we use a non-linear production function. Unlike Hackett (1993) and Hacket (1994), we do not focus on the incomplete contract aspect of the team interaction. In our experiment, the only source of uncertainty is the choices of the participants.

In this paper, we ask whether ex-post negotiations can help the players find a more efficient allocation. We consider a small team of only two players. Both players invest in a joint production process and then split joint benefits. We compare two institutions: In one (contract), players choose a fixed division of the produced amount, before they decide investments. In the other (hold-up), players first invest, and then play a Nash demand game to divide joint profits. [1]

With selfish and rational players, the institution with a fixed division of the produced amount (contract) is expected to yield underinvestment from the players. Instead, the institution where players first invest and then play a Nash demand game to divide profits (hold-up) has efficient equilibria. The commitment that is inherent in the Nash demand game should allow players to choose efficient investment levels which are not an equilibrium in the institution with a fixed division of the produced amount.

But, as Engel (2006) points out, players are not necessarily selfish and rational. Real players, who are not selfish and who are boundedly rational, might benefit from these two institutions in a different way. In a slightly different context, for unilateral investments, this question has been addressed by Ellingsen and Johannesson (2004a). While Ellingsen and Johannesson (2004a) observe that ex-post negotiation can be beneficial, they also find that players may follow different standards and, thus, miscoordinate. Here, we look at a situation where investments are bilateral. We use the strategy method to elicit the norms that are used by

1 A different possible approach is to implement ex-post negotiation as a bargaining game with alternating offers as, e.g., in Sonnemans, Oosterbeek, and Sloof (2001), Oosterbeek, Sonnemans, and Velzen (2003), R. Sloof, Sonnemans, and Oosterbeek (2004), Davis and Leider (2018), or as an ultimatum game, e.g., Ellingsen and Johannesson (2004b), Randolph Sloof, Oosterbeek, and Sonnemans (2007), Morita and Servátka (2013), Morita and Servátka (2018), Haruvy et al. (2019).

players directly. We find that players seem to coordinate on an inefficient norm that does not take into account players' prior investments.

In the institution with fixed divisions of profits, we observe the type of the division and the impact of the status quo contract. An "efficient" division provides second-best incentives, an "egalitarian" contract splits the joint production evenly. Although, in equilibrium both players benefit from an efficient contract, weak (less productive) players expect in the experiment to gain more from the egalitarian contract. More productive players instead, bid for a more "efficient" contract which would provide second-best incentives.

B. Experiment

I. Contracts and Hold-ups

In our experiment[2] we compare two treatments:

Hold-up

> In the 'hold-up' situation, players choose their investments first. Thereafter, players play a Nash demand game to negotiate a division of their joint profit. We use the strategy method to implement the Nash demand game. Since many equilibria of the Nash demand game are efficient, selfish players could obtain an efficient outcome.

Contracts

> In the 'contract' situation, players first determine the terms of a contract, i.e., how to divide the surplus of a joint investment that is to occur at a later stage. Here we restrict ourselves to sharing rules, i.e., to contracts that divide the joint profit according to some pre-specified share. Sharing rules are common and have been used already in the

2 The experiment was implemented in z-Tree (Fischbacher 2007). For the statistical analysis we use R (R Core Team 2025). Bayesian analysis is done with JAGS (Plummer 2003). Data and methods are available at https://www.kirchkamp.de/research/pubGood.html.

medieval Islamic world in the institution of qirad (see Sapuan 2016). Profit sharing rules can be found today in contracts of suppliers for the automotive industry, in company-community partnerships (e.g., in fair trade) but also in crop-sharing rules.

Given a sharing rule, both players simultaneously choose investments, and then profits are distributed according to the negotiated contract.

To simplify matters, players will only choose between two contracts, one asymmetric efficient contract and one egalitarian contract. This allows us to use the strategy method and to elicit investment levels for both contracts, even if only one of the two contracts is implemented. Allowing only two possible sharing rules is not unrealistic. Contracting parties often choose only between a small number of contracts. E.g., a majority of farmers in Ohio use either a 50:50 sharing rule or a $^2/_3$:$^1/_3$ sharing rule (Breece and Forster 2001).

In both treatments participants are randomly matched for 20 periods.

Güth et al. (2003) also study an experiment where hold-up is possible and where players can choose a contract. Unlike Güth et al. (2003) we do not ask whether players give up bargaining power to gain more efficiency. While in their experiment asymmetric productivities and bargaining powers are chosen by players, in our experiment bargaining power and productivities are fixed.

In Fehr, Kremhelmer, and Schmidt (2008), players decide sequentially. The investment of a first player is observed by the second player who then determines their investment. Although an egalitarian division of profits would in equilibrium be inefficient, Fehr, Kremhelmer, and Schmidt (2008) find that in their experiment the egalitarian contract yields the highest investments.

Hacket (1994) and Oosterbeek, Sonnemans, and Velzen (2003) both study hold-up situations where, after production, players have no commitment power at all but engage in bargaining with alternating offers. In our hold-up treatment profits are divided with a Nash demand game, i.e., players can commit to a demand. Theoretically this should remove the hold-up problem.

Zhang and Bayer (2024) study a hold-up situation where players use a contest to divide profits. In their experiment, Zhang and Bayer (2024) find contracts to be more efficient than wasteful investments into a contest.

Our experiment is closer to Ellingsen and Johannesson (2004a) who also use a Nash demand game. While they put a focus on the effect of communication, we, instead, compare the hold-up treatment with a treatment where contracts are possible.

Our research question is also similar to Bruttel and Eisenkopf (2012) who ask whether an unfair contract can enhance welfare over a situation without contracts.

II. Investments and Payoffs

In this experiment we study the situation of two players, A and B. Players differ in productivity and status quo rights. Each player has an own initial endowment M_A=M_B=500. Simultaneously, both players decide to invest a part of their endowment. The joint output $Q\left(I_A, I_B\right)$ depends on investments I_A and I_B.

$$Q\left(I_A, I_B\right) = S \cdot I_A^{\alpha} \cdot I_B^{\beta} \tag{1}$$

In our experiment, productivities of the two players A and B are α=0.315, β=0.427. The parameter S=21.89.[3] We call player B the one who is more efficient, i.e., the one whose investment has the larger exponent, β=0.427. We call player A the one who is less efficient, i.e., the one whose investment has the smaller exponent, α=0.315. We compare two treatments. One, we call 'hold-up', the other we call 'contracts'.

1. The hold-up treatment

In the 'hold-up' treatment players choose their investments I_A and I_B first. Thereafter, players play a Nash demand game to negotiate a division of their joint profit. Players A and B demand shares D_A and D_B of their joint profit. If the sum of the demands $D_A + D_B$ is smaller or equal than the total profit, then players obtains their demands. Otherwise players obtain nothing. Payoffs are as follows:

$$u_A = \begin{cases} D_A - I_A & \text{if } D_A + D_B \leq M_A + M_B + S \cdot I_A^{\alpha} \cdot I_B^{\beta} \\ -I_A & \text{otherwise} \end{cases} \tag{2}$$

3 These numbers are chosen to exclude multiple equilibria and to maximise the difference between the equilibrium of the 'egalitarian' and the 'efficient' contract.

$$u_B = \begin{cases} D_B - I_B & \text{if}\, D_A + D_B \leq M_A + M_B + S \cdot I_A^{\alpha} \cdot I_B^{\beta} \\ -I_B & \text{otherwise} \end{cases} \tag{3}$$

Demand functions are as follows:

$$D_i = \phi_i \left(M_A + M_B + S \cdot I_A^{\alpha} \cdot I_B^{\beta} \right) + \rho_i \left(I_{\text{own}} - I_{\text{other}} \right) \tag{4}$$

Parameter values $\phi_1 = \phi_2 = ½$ and $\rho = 0$ would describe a 'split the revenue' rule. Parameter values $\phi_1 = \phi_2 = ½$ and $\rho = ½$ would describe a 'split revenue–cost' rule.

In each round, players choose their own investment I_i and the two parameters, ϕ_i and ρ_i, of the demand function in Equation (4). Players make these choices simultaneously, i.e., players can't condition their investment on the outcome of the demand game.

To learn more about expectations and in line with the 'contract' treatment, we also ask for the expected contribution of the opponent.

what do you expect the other player to contribute?

your own contribution	0	50	100	150	200	250	300	350	400	450	500
0	500	500	500	500	500	500	500	500	500	500	500
50	500	899	1036	1138	1221	1293	1357	1416	1469	1519	1566
100	500	996	1167	1293	1397	1487	1567	1639	1706	1768	1826
150	500	1064	1258	1401	1519	1621	1712	1794	1870	1941	2007
200	500	1117	1330	1487	1616	1727	1827	1917	2000	2078	2150
250	500	1162	1390	1559	1697	1817	1923	2020	2109	2192	2270
300	500	1201	1443	1621	1768	1895	2008	2110	2205	2293	2375
350	500	1236	1490	1677	1831	1964	2083	2190	2289	2382	2468
400	500	1268	1533	1728	1888	2027	2151	2263	2366	2463	2553
450	500	1297	1572	1774	1941	2085	2213	2329	2437	2537	2630
500	500	1324	1608	1817	1989	2138	2271	2391	2502	2605	2702
Jointly produced:	500	1236	1490	1677	1831	1964	2083	2190	2289	2382	2468
You demand:	330	646	745	815	869	914	952	986	1015	1042	1066
To agree, the other may not demand more than...	170	590	744	862	962	1050	1130	1205	1274	1340	1403
If you two agree...											
your payoff is:	-20	296	395	465	519	564	602	636	665	692	716
the max. payoff of the other is:	170	540	644	712	762	800	830	855	874	890	903
If you two do not agree (sum of both demands is larger than joint production)...											
your payoff is:	-350	-350	-350	-350	-350	-350	-350	-350	-350	-350	-350
the max. payoff of the other is:	0	-50	-100	-150	-200	-250	-300	-350	-400	-450	-500

click here to determine your demand:

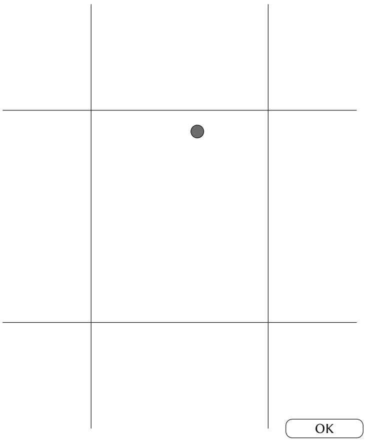

Figure 1: The experimental interface for the 'hold-up'-treatment.[4]

4 Participants were guided to specify first their expectation about the other player by choosing a column and their own intended contribution by choosing a row in the table. Then they were asked to specify the parameters of their demand function by clicking in the area on the right. They could adjust their strategies (and see how these adjustments would affect the outcomes on the bottom part of the table) as often as they wanted, before moving to the next stage by clicking 'OK'.

Figure 1 shows the experimental interface for the 'hold-up' treatment. In each round of the experiment, participants would first only see the upper left part of the interface, that is only the table with mutual payoffs. First they had to provide their expectations for the choice of the other player and choose an own contribution. Once they had made their choice, participants would also see the 'demand-calculator' in the right part of the screen as shown in Figure 1. Each click into the field on the right sets the parameters of the demand function. Their own choice would be shown as a red dot, lines would give some orientation and would allow them to start with similar choices in the next period. The vertical axis would describe ϕ_i and the horizontal axis would describe ρ_i. The lower horizontal line denotes ϕ_i=0 while the upper line denotes ϕ=½. The vertical line on the left corresponds to ρ=0 while the line on the right corresponds to ρ=½.

Upon each click participants would see in the bottom part of the left table their actual demand and individual payoffs depending on the choices of the other player. Participants could adjust their own choices and expectations and the parameters of their demand as often as they wanted.

2. The contract treatment

In the treatment with contracts, these contracts are determined by a sharing rule π. Payoffs are as follows:

$$u_A = M - I_A + \pi \cdot S \cdot I_A^\alpha \cdot I_B^\beta - p \tag{5}$$

$$u_B = M - I_B + (1-\pi) \cdot S \cdot I_A^\alpha \cdot I_B^\beta + p \tag{6}$$

Here p is the price paid or received by A for the contract. Different from the hold-up situation, in this contract investments are fully borne by the investing player. Since π is determined ex-ante, players can condition their investment on the terms of the contract.

To keep the experiment simple, we consider only two sharing rules: π=0.5 (the egalitarian contract) and π=0.44 (the efficient contract).[5] If players' investments were the same, I_A=I_B, then with the egalitarian contract π=0.5 their payoffs were the same. With the efficient contract π=0.44

5 For our parameter values the contract that in equilibrium maximises joint surplus is $\pi\approx$0.43995. Hence, the 'efficient' contract we use in the experiment, π=0.44, is a close approximation.

their payoffs were different in this situation. However, since in equilibrium under the efficient contract the more productive person invests more, total profit might be higher for both players. Selfish players would prefer the equilibrium outcome under the efficient contract over the outcome under the egalitarian contract.

Before players choose investments, they determine the contract. To do this, players submit bids b_A and b_B for one of the two contracts (either for π=0.44 or for π=0.5).

- If both players bid for the same contract, then this contract is used and the price is p=0.
- If the two players bid for different contracts, then the contract with the higher bid is implemented. The winning bidder pays the own bid to the other player.

$$p = \begin{cases} b_A & \text{if } b_A > b_B \text{ and bids are for different contracts.} \\ -b_B & \text{if } b_A < b_B \text{ and bids are for different contracts.} \\ 0 & \text{otherwise.} \end{cases}$$

- If both bids are the same and for different contracts or if both bids are zero, then a so called 'default' contract is used. Our implementation of the default contract is framed in a neutral way.

(The "egalitarian" table: $\pi = 0.5$)

player A \ player B	1	2	3	4	5	6	7	8	9	10	11
1	500 500	450 500	400 500	350 500	300 500	250 500	200 500	150 500	100 500	50 500	0 500
2	500 450	649 649	668 718	669 769	661 811	647 847	629 879	608 908	585 935	560 960	533 983
3	500 400	698 648	734 734	747 797	748 848	743 893	733 933	720 970	703 1003	684 1034	663 1063
4	500 350	732 632	779 729	801 801	810 860	811 911	806 956	797 997	785 1035	770 1070	754 1104
5	500 300	759 609	815 715	843 793	858 858	864 914	863 963	859 1009	850 1050	839 1089	825 1125
6	500 250	781 581	845 695	879 779	899 849	908 908	912 962	910 1010	905 1055	896 1096	885 1135
7	500 200	801 551	872 672	911 761	934 834	947 897	954 954	955 1005	952 1052	946 1096	937 1137
8	500 150	818 518	895 645	939 739	965 815	982 882	991 941	995 995	995 1045	991 1091	984 1134
9	500 100	834 484	916 616	964 714	994 794	1013 863	1025 925	1031 981	1033 1033	1031 1081	1026 1126
10	500 50	849 449	936 586	987 687	1020 770	1042 842	1056 906	1065 965	1068 1018	1068 1068	1065 1115
11	500 0	862 412	954 554	1009 659	1045 745	1069 819	1085 885	1096 946	1101 1001	1103 1053	1101 1101

Your bid for this table:

(the "efficient" table: $\pi = 0.44$)

player A \ player B	1	2	3	4	5	6	7	8	9	10	11
1	500 500	450 500	400 500	350 500	300 500	250 500	200 500	150 500	100 500	50 500	0 500
2	500 450	673 626	700 686	707 731	704 767	694 799	680 827	663 853	643 877	621 899	597 919
3	500 400	728 618	774 694	794 749	802 795	803 834	797 869	788 901	775 931	760 958	743 984
4	500 350	766 598	825 684	855 747	871 798	878 843	879 883	875 919	867 953	857 984	844 1013
5	500 300	796 572	865 665	903 734	925 791	937 840	943 884	944 924	940 960	933 994	924 1026
6	500 250	821 541	899 642	943 716	970 777	987 829	997 876	1001 919	1001 958	998 995	991 1029
7	500 200	843 509	928 615	978 693	1010 758	1031 814	1044 863	1052 908	1055 950	1054 989	1050 1025
8	500 150	862 474	954 586	1009 668	1045 736	1070 794	1086 846	1097 894	1102 937	1104 978	1102 1016
9	500 100	880 438	978 554	1038 640	1077 711	1105 772	1124 826	1137 876	1145 921	1149 964	1150 1003
10	500 50	896 401	1000 521	1063 611	1107 684	1137 747	1159 804	1175 855	1185 902	1191 946	1193 987
11	500 0	911 363	1020 487	1088 580	1134 655	1167 721	1192 779	1209 832	1221 881	1229 926	1233 969

Your bid for this table:

The highest bid determines the game. The winner pays his bid to the other player. If both bids are the same, then the left game is played.

Figure 2: The experimental interface for the 'contract'-treatment.[6]

Figure 2 shows the decision screen in the 'contract' treatment. The screen shows two tables, each table representing one 'contract'. Which of the two tables shows the 'efficient' and which the 'egalitarian' contract was determined randomly for each experimental session. To submit choices (investments) for the two contracts, players click on a row for each of the two tables. Players are also asked to submit expectations by clicking on a column for each table. To determine which table will actually be used, players can make bids for either the left or the right table on the screen. The player with the higher bid wins and determines the game that is played, i.e., essentially whether π=0.44 or whether π=0.5. If players do not bid or submit the same bid as the other player (this is what 23.6 % of all bidders do) then the default contract is implemented. The default contract was determined randomly for each session and known to participants.

Table 1 provides an overview of the treatments.

Table 1: List of treatments.

treatment	**obs**	**participants**
contract	20	182
holdup	45	404
total	65	586

C. Hypotheses

I. Hypotheses for the contract game

Hypothesis 1 (Efficient sharing rule): *Both players should prefer the theoretically efficient sharing rule π=0.44.*

In a different game where players decide sequentially, Fehr, Kremhelmer, and Schmidt (2008) find that the egalitarian sharing rule, although not efficient in equilibrium, maximises investments in the experiment.

6 In each table, best replies are shown in red. Nash equilibria are denoted with a blue circle. This information was not provided in the experiment. All numbers in the experiment were shown in black. Also, no information about the values of π and 'egalitarian' and 'efficient' was shown. In about half of our sessions the layout was reversed, i.e., the table that we show here on the right was shown on the left and vice versa.

Engel and Kurschilgen (2013) explain that customs and normative expectations shape behaviour. The default sharing rule in our game can be seen as such a normative expectation. This rule is, however, an expectation that players can easily override by making a very small bid.

Hypothesis 2 (Irrelevance of default): *We expect that the default sharing rule has no influence on the sharing rule that is chosen by the players.*

II. Hypotheses for the hold-up game

Since strategies can be characterised as cost shares ρ and revenue shares ϕ_A and ϕ_B, Figure 3 shows how these parameters determine investments and profits in equilibrium. Since only eleven different investment levels are allowed, the contour lines are not smooth. Small values of ρ lead to underinvestment. Larger values of ρ allow sharing investment costs and help obtain an efficient outcome.

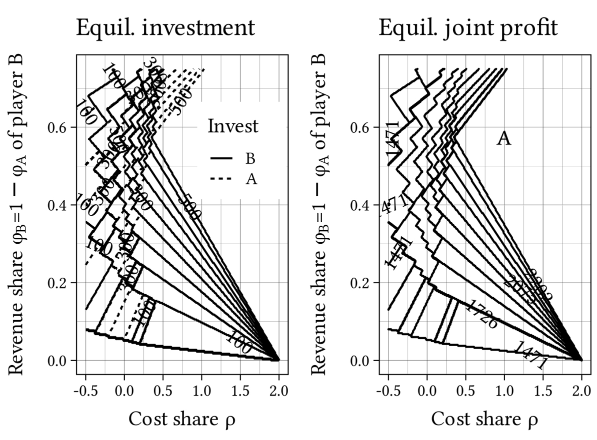

Figure 3: Contours of equilibrium investments (left) and joint profits (right) in the hold-up game in the experiment depending on fairness norms.

To obtain efficient investments in equilibrium, ρ can be as small as ρ=0.347, provided that the strong player obtains a small extra incentive to invest to compensate for the weak players less efficient technology, i.e., the strong player's share is 0.574 and the weak player's share is 0.426.

If, instead, players use a 50:50 norm, they have to take into account more of their investments in the Nash demand game, i.e., to obtain equilibrium efficient investments with ϕ=½ we need $\rho \geq 0.56$.

> **Hypothesis 3 (Efficient norms in the hold-up game):** *We expect that participants coordinate on fairness norms, expressed as ϕ and ρ, that allow them to obtain the maximum joint profit, i.e., norms in range 'A' in Figure 3.*

If players are interested in a sharing norm which is robust to different levels of ρ then they should give extra incentives to the strong player.

> **Hypothesis 4 (Strongly efficient norms in the hold-up game):** *The strong player's share will be larger than 1/2 and close to 0.574.*

In the hold-up treatment players can make efficient investments in an equilibrium. Equilibrium investments in the contract treatment are lower.

> **Hypothesis 5 (Efficient investment in the hold-up game):** *We expect that participants obtain higher joint profits in the hold-up treatment than in the contract treatment.*

III. Comparison of both treatments

If players select the efficient equilibrium in the Nash-demand game they will choose higher investment levels and, hence, have higher joint profits than in the equilibrium of the contract game.

> **Hypothesis 6 (More efficiency in the hold-up treatment):** *We expect that investments and payoffs in the hold-up treatment are higher than those in the contract treatment.*

D. Results

I. Some descriptives

Of the 586 participants 326 were female, 206 were male, for 54 we do not know their gender. The left graph in Figure 4 shows the distribution of the age of the participants. The right graph in Figure 4 shows a histogram of the perceived difficulty of the experiment. Apparently, most participants found the experiment easy to understand.

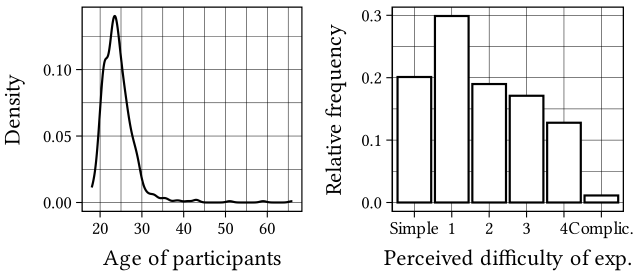

Figure 4: Age of participants and perceived difficulty of the experiment

II. Results for the contract game

1. Bids for contracts

According to Hypothesis 1, we expect both players to prefer the efficient sharing rule π=0.44. Figure 5 shows the distribution of bids for egalitarian and efficient contracts.

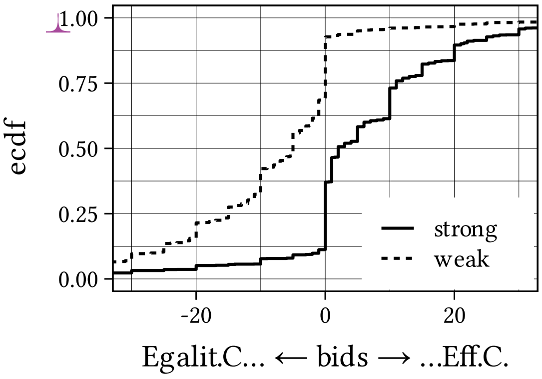

Figure 5: Distribution of bids

Positive bids in Figure 5 denote bids for the efficient contract (π=0.44). Negative bids denote bids for the egalitarian contract (π=0.5). In line with Hypothesis 1, the strong player bids most of the time for the efficient contract (most of the dotted distribution is to the right of 0). Different from what we expect in Hypothesis 1, the weak player bids most of the time for the egalitarian contract (most of the solid line distribution is to the left of 0).

To study this more formally, we estimate the following mixed effects regression

$$b_{ijk} = \beta_{\text{weak}} d_{\text{weak}} + \beta_{\text{strong}} d_{\text{strong}} + \eta_{kj} + \nu_j + u_{ijk} \tag{7}$$

where η_{kj} is a random effect for player k in group j, ν_j is a random effect for the matching group in the experiment, u_{ijk} is the residual, d_{weak} and d_{strong} are dummies for the two types of players and b_{ik} is player i's bid for the efficient contract in round k.

We estimate β_{weak}=-8.68, CI_{95}=[-11.7, -5.59]. The odds of $\beta_{\text{weak}} < 0$ are larger than 1000:1. We have, hence, "very strong" evidence that the weak player prefers the egalitarian contract.[7]

2. Effect of the default contract

According to Hypothesis 2, we expect the default sharing rule to have no influence on the choice of the sharing rule. Indeed, for the strong player, the effect of a default efficient contract on the bid for the efficient contract is, in line with Hypothesis 2, only -0.906, CI_{95}=[-7.32, 5.6].[8] For the weak player the effect of a default efficient contract on the bid for the efficient contract is 3.53, CI_{95}=[-2.98, 9.94]. The odds that the effect of the default are positive are 6.06:1, i.e., we have at least "positive" evidence that the weak player's bids for the egalitarian contract are larger if the egalitarian contract is the default.

7 We follow the terminology suggested by Kass and Raftery (1995): odds $\in [1:1, 2.72:1]$: only anecdotal evidence, odds $\in [2.72:1, 20.1:1]$: positive evidence, odds $\in [20.1:1, 148:1]$: strong evidence, odds $\in [148:1, \infty:1]$: very strong evidence.

8 We use a specification similar to Equation (7), with an interaction for the default contract.

III. Results for the hold-up game

1. Norms

According to Hypothesis 3, we expect that participants coordinate on fairness norms that are compatible with maximising joint profits. These norms are shown as range 'A' in Figure 3. Figure 6 shows the norms that we observe in the experiment. Contour lines show the distribution of norms in the experiment. The shaded area shows the range of norms that would yield a profit maximising equilibrium.

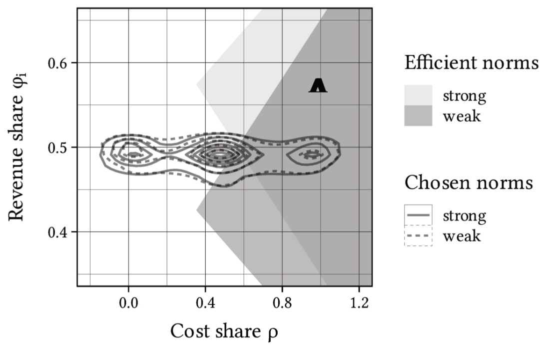

Figure 6: Norms in the hold-up game.

Different from Hypothesis 3 the majority of players does not take into account investments in a way that would support efficient investments in equilibrium.

We find that the norms of weak and strong players are very similar. There is no asymmetry as expected in Hypothesis 4. We estimate[9] an average ϕ_i=0.46, CI_{95}=[0.45, 0.47]. We do not find a substantial difference between ϕ_A and ϕ_B. The odds that $\phi_B > \phi_A$ are only 1.86:1. We estimate an average ρ=0.444, CI_{95}=[0.407, 0.482]. Again, we do not find a substantial difference between ρ_A and ρ_B. The odds that $\rho_B > \rho_A$ 1:2.04. We can neither confirm Hypothesis 3 nor Hypothesis 4.

9 We follow the specification of Equation (7), only with ρ_{ijk} and ϕ_{ijk} as dependent variables.

2. Efficiency of contracts versus hold-up

According to Hypothesis 5, we should expect higher joint profits in the hold-up treatment.

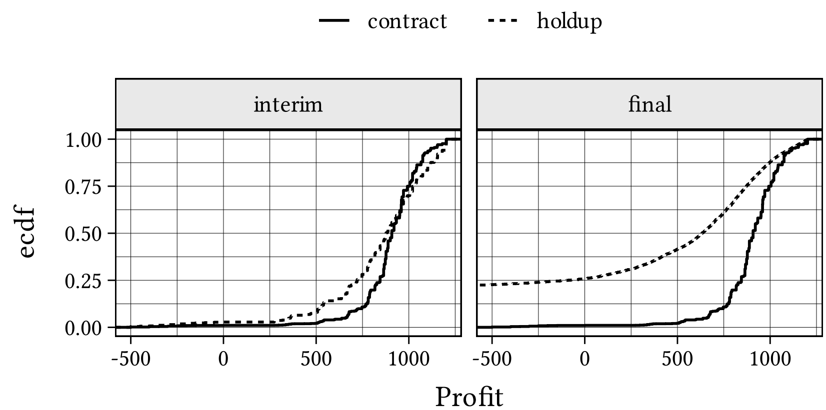

Figure 7: Distribution of produced output in the hold-up and contract treatment.

The left part of Figure 7 shows the distribution of the amounts produced. We see that the amount produced in the hold-up treatment is slightly lower than the amount produced in the contract treatment. While no agreement is necessary after production in the contract treatment, only 79 % of the players find an agreement in the hold-up treatment. This lack of agreement in the hold-up treatment leads to even lower profits. The right part of Figure 7 shows the distribution of final profits. Contrary to Hypothesis 5, actual profits in the hold-up treatment are much lower than profits in the contract treatment.

E. Discussion

In this paper, we have compared two treatments: one treatment describes a hold-up situation where players first invest; then they divide the proceeds of their joint investment with the help of a Nash demand game. The other treatment describes a contract situation where players negotiate a contract before their investment.

Rational players should be able to coordinate on an efficient equilibrium in the hold-up situation. In equilibrium, payoffs can be higher in the hold-up treatment than in the contract treatment. However, in the experiment players fail to coordinate in the hold-up game. This failure to coordinate primarily makes the hold-up game less efficient than the contract game.

We expected players to adopt different norms for weak and strong players. Instead, the norms used in the experiment were rather egalitarian and did not seem to depend on the players' strength. Such egalitarian norms made coordination on efficient investments more difficult.

In the contract treatment, we compared two contracts: an asymmetric one and a symmetric one. In equilibrium, the asymmetric contract should provide better incentives for the more productive player, so that, in equilibrium, both players would earn more with the asymmetric contract than they would with the symmetric one. In the experiment, however, the less productive player preferred the symmetric contract. To some degree, this choice can be justified through concerns for efficiency. To some extent, however, the less productive player clearly overestimates the investment made by the other player.

In this paper, we explored how players' contributions to a public good depend on institutions. Perhaps unsurprisingly, we found that contributions often deviate from equilibrium predictions. Importantly, we found that the direction of these deviations depends on the institution. Consequently, institutions that are theoretically less efficient in equilibrium sometimes proved to be more efficient in the experiment. Here, we did not include social preferences in the derivation of theoretical benchmark solutions. Future research should delve into the specific cognitive and behavioral factors that influence players' deviations from equilibrium predictions. Employing experimental designs that isolate players' expectations and concerns for overall efficiency could provide valuable insights. Additionally, understanding these dynamics could have significant implications for the design of institutions and policies aimed at enhancing efficiency in public goods scenarios.

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