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Cooperation and Distributive Conflict

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Abstract

If either property rights or institutions are weak, agents who create wealth by cooperating will later have an incentive to fight over the distribution of it. In this paper we investigate theoretically and experimentally the circumstances under which welfare losses from investment in distributional contests destroy welfare gains from voluntary cooperation. We find that in situations, where the return to cooperation is high, subjects cooperate strongly and welfare exceeds the predicted non-cooperation levels. If returns to cooperation are low, then subjects still cooperate, but the resources wasted in the distributional conflict lead to lower welfare than if subjects had followed the theoretical prediction of not cooperating.

- Keywords: Conflict, Cooperation, Contests, Experiments
- JEL Classification: D74, C91

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1 Introduction

Whenever the cooperation of individuals generates surpluses for which no well defined property rights exist, a distributive conflict might arise. If rational actors foresee that the distributive conflict could become very severe they might refrain from cooperating in the first place. This creates a hold-up problem. However, one can also imagine that actors do not foresee the damaging nature of distributive conflict over the surplus created by cooperation, such that they end up worse off than if they had not cooperated at all. Some historical examples like the Balkan conflict, the Aceh wars or the Sri Lankan civil war come to mind. Initial cooperation and the following conflict or civil war left these regions much worse off.[1] The same phenomenon is observed in other, smaller environments. After a bitter divorce battle the parties are often worse off than before they entered a marriage. The same is true for many joint ventures in the business world that have gone sour. This is even more often the case in criminal joint ventures, where property rights are not enforceable at all. Distributive conflicts over the proceeds from criminal activity often lead to considerable collateral damage.[2]

The contribution of this paper is a clean investigation of the impact of cooperation and consecutive fighting for its proceeds on welfare. Compared to other studies our main methodological advancement is that we are shutting down other mechanisms that could have an impact on welfare. In order to achieve this, we develop a simple model capturing the essence of the problem. The empirical evaluation is made possible by taking the model to the laboratory. Our study is in the spirit of other recent papers that use laboratory experiments with contests in order to study conflict situations (like Kimbrough and Sheremeta, 2013, 2014; Kimbrough et al., 2014).

Our simple model has two stages. In stage one two players invest simultaneously into a group project, where the resulting value of the project is a multiple of the total investment. In stage two, after observing the total value of the group project, players simultaneously exert costly effort with the aim to secure a share of the created value. The share a player receives is equal to her share of total efforts exerted.

[1] See Hirshleifer (2001), Grossman (1991, 1999), Grossman and Kim (1995) and Collier and Hoeffler (2004) for theories on the impact of material objectives on violent conflicts and civil wars. See also the econometric study and the case studies in Sambanis and Collier (2005a,b) for a comprehensive investigation of "greed versus grievance" as causes of civil wars, which shows that material objectives are important.

[2] For a beautiful dramatic illustration of this mechanism at work, watch the movie "The Treasure of the Sierra Madre" with Humphrey Bogard, which was suggested to me by Phil Grossman.

First, we analyse a situation, where initial investment does not restrict the amount of effort available in the distributional contest. This is the case if, e.g., investment and effort are not taken from the same budget. One can think of situations, where efforts are physical and investments are financial or vice versa. Examples are illegal joint ventures such as drug syndicates with violent distributional battles or group production with court battles over the distribution of the returns. Cooperative investments does also not reduce the budget available for fighting in cases where both investments and efforts are financial but the maximum investment is small compared to the total budget. Take multinationals investing in a joint venture for example. There the maximum amount reasonably invested in a joint venture is often small compared to the total assets of a firm. Then investing an extra Dollar into the joint venture will not significantly reduce the resources available for a potential court battle over the proceeds.

Our analysis shows that up to very high social returns for contributions a rational player would not cooperate (i.e. invest in the group project). We know from many experimental studies that subjects often cooperate in social dilemmas, though (Ledyard, 1995; Chaudhuri, 2011). It is interesting to explore the consequences for subjects that cooperate in the investment stage. For low social returns cooperation is actually welfare damaging when followed by optimal efforts, since the resources burned in the contest are greater than the surplus created from cooperating. Cooperation in the investment stage is only welfare enhancing if followed by efforts well below the equilibrium level. For higher social returns cooperation followed by equilibrium efforts is welfare increasing but still not individually rational.

The insight that the inability to commit to not fighting in the future is a major cause of a severe hold-up problem motivates a variant of our model with constrained fighting efforts. Here the players have to finance their investment and their fighting effort from the same limited pool of resources. This is not only of theoretical interest but also describes many real world situations. For example, in contrast to multinationals, venture capitalists often only raise a certain amount of capital they can use in a joint venture. The investment into the joint venture and also potential fees for lawyers in subsequent distributive conflicts have to be paid out of it. Sports is another area where both investments into the joint project and efforts to secure the largest share of the proceeds come from the same pool of resources. Players have to invest from their pool of physical stamina into the team success as well as into their own fame, which influences the share of the team surplus they receive through salaries, etc. A more specific example are break-aways in cycling. Riders in a breakaway have to use their legs when cooperating with the aim to stay away from the peleton. However, they will lack the power expended, when the final sprint comes along, which decides who wins and who gets how much of the prize money.

While the same zero-contribution equilibrium as in the unconstrained case exists for the same range of social returns, the resource constraint also allows for other more efficient equilibria. The intuition is the following: if both players invest a relatively high level of their resources into the joint project then they cannot fight very hard anymore as they do not have much resources left. This might make investing worthwhile. Investing the full endowment is not an equilibrium though, as then the opponent could invest a little less and steal the whole surplus with a little bit of effort.

With these theoretical predictions in hand we implement a two-by-two experimental design in the laboratory. We vary the marginal social return to investment (low vs. high). On the other dimension we vary if the efforts in the conflict stage have to come out of the same endowment as the first-stage investment (constrained vs. unconstrained). We find in contrast to much of the contest literature that subjects' average efforts are remarkably close to equilibrium. As subjects – this time contrary to equilibrium predictions – also contribute, we observe welfare damaging play in the low return treatments. Subjects learn with repetition and reduce their contributions such that the welfare losses become small in the final stages of the experiment. For high social returns without constraints on effort, subjects overcome the social dilemma and social welfare is about 50 percent above the prediction. In the constrained case subjects also make positive contributions. These are lower than in the unconstrained case, as subjects are careful not to become defenseless in the distributive conflict. The lower resulting efforts cannot fully compensate for the lower surplus generated and so contrary to the theoretical prediction welfare is lower than in the unconstrained case. The constraints, on the one hand, are useful to limit welfare reducing cooperation when the social return to cooperation is low. On the other hand, constraints are hindering subjects to fully realize welfare gains from cooperation when the returns are high.

The remainder of the paper is organized as follows. The next Section lays out the underlying model and derives equilibrium predictions. Section 3 describes the experimental design. Section 4 reports and discusses our results. We end with some concluding remarks in Section 5.

2 The model

In what follows we lay out our model. We combine a simple version of a cooperation game (a linear two-player voluntary contribution mechanism) with the simplest version of a distributional contest (a two-player Tullock contest, Tullock 1980). In the first stage, players voluntarily invest in a group project. Then in the second stage, after observing the value of the group project, players simultaneously exert costly effort in a distributive contest. The share of value from the group project a player receives is proportional to the ratio of her own effort to the total effort exerted.

Implicitly, our setup assumes that players cannot commit to parting amicably without fighting. Also binding contracts specifying amicable splits are not possible. Hence, our model captures situations, where there exists an inherent temptation to fight for a larger part of the pie. This does not mean that a fifty-fifty split without fighting is impossible in our model, since both parties not exerting any effort would accomplish this.[3]

We denote player $i's$ investment in the group project as c_i and her effort exerted in the contest as e_i. Further we denote a player's endowment as C, the value of the group project as $V(c_i, c_j)$ and the value share accruing to i as $\rho_i(e_i, e_j)$. Given this notation we can write the profit of player i as:[4]

$$U_i(c_i, c_j, e_i, e_j) := C + \rho_i(e_i, e_j)V(c_i, c_j) - c_i - e_i \tag{1}$$
$$c_i, c_j \in [0, C]$$
$$e_i, e_j \in [0, \infty]$$

For simplicity we use a standard Tullock contest function:

$$\rho_i(e_i, e_j) := \begin{cases} \frac{e_i}{e_i+e_j} & if \quad e_i + e_j > 0 \\ 1/2 & if \quad e_i + e_j = 0 \end{cases} .$$

The value of the group project depends linearly on the investments and on the marginal social return to investment, MSRI, which we denote by ϕ :

$$V(c_i, c_j) := \phi(c_i + c_j).$$

[3] A referee pointed out that this feature of the model is quite helpful for the analysis of the data, since efforts do not suffer from the selection bias that would arise if they were only observed conditional on the previous decision to fight.

[4] We normalise the marginal cost (measured as a money equivalent) for both effort and investment to one.

We opted for a linear VCM for two reasons. Firstly, the wide use of linear VCMs in the literature allows a direct comparison of results. Secondly, and more importantly, a linear VCM is much easier to understand for experimental subjects than a non-linear version. Since we already have a stage with non-linear profits in the Tullock contest, keeping the cooperation stage as simple as possible is a sensible way to ensure that subjects understand the payoff structure.

With respect to the effort in the distributional contest different scenarios are imaginable. The effort could be either taken from the same resources as the investment (e.g. wealth invested in a joint venture and expenditure for lawyers in the fight for the proceeds) or from a different source (e.g. investment could be monetary and investment could be physical or time, etc.). We will consider both cases.

Definition 1 *In what follows we will look at two scenarios with regard to the strategy space for effort.*
a) We speak of the ***unconstrained case*** *if the admissible action spaces are*

$$\begin{aligned} c_i &\in [0, C],\ i \in \{1,2\} \\ e_i &\in [0, \infty],\ i \in \{1,2\} \end{aligned}$$

b) We speak of the ***constrained case*** *if*

$$\begin{aligned} c_i &\in [0, C],\ i \in \{1,2\} \\ e_i &\in [0, C - c_i],\ i \in \{1,2\}\,. \end{aligned}$$

It is easy to see that social efficiency requires zero efforts, since efforts are costly and only decide over distribution. Adding up the payoffs of both players gives

$$U_i + U_j = 2C + \phi(c_i + c_j) - c_i - c_j - e_i - e_j, \tag{2}$$

which also shows that full investment is socially efficient as long as $\phi > 1$. This is true independently of the existence or absence of constraints on the efforts.

Proposition 1 *The social efficient contributions and efforts for both cases are* $\forall i \in \{1,2\}$, $i \neq j$

$$\begin{aligned} e_i^S &= 0 \\ c_i^S &= \begin{cases} 0 & if \quad \phi < 1 \\ \in [0, C] & if \quad \phi = 1 \\ C & if \quad \phi > 1. \end{cases} \end{aligned}$$

2.1 Equilibrium in the unconstrained case

We use Subgame Perfect Nash Equilibrium as the solution concept. Any possible pair of initial investments induces a separate subgame. For given initial investments the best response for player i in stage two is determined by the first-order condition

$$\frac{\partial}{\partial e_i} U_i(V, e_i, e_j) = \frac{e_j}{(e_i + e_j)^2} V - 1 = 0.$$

Observe that player i and $j's$ first-order conditions are symmetric. Solving yields:

$$e_i^*(V) = e_j^*(V) = V/4.$$

Now move to the first stage. The expected payoff of player i, who anticipates equilibrium play in the second stage, becomes:[5]

$$\begin{aligned} U_i(c_i, c_j, e_i^*, e_j^*) &= C + V/4 - c_i \\ &= C + \frac{\phi}{4}(c_i + c_j) - c_i. \end{aligned}$$

It is easy to see that player i chooses to contribute her full endowment C if $\phi > 4$, while she does not contribute anything if $\phi < 4$. We get the following subgame-perfect equilibrium for the unconstrained case.

Proposition 2 *In the unconstrained case in equilibrium we have* $\forall i = 1, 2, i \neq j$

$$\begin{aligned} e_i^* &= \frac{\phi}{4}(c_i + c_j) \\ c_i^* &= \begin{cases} 0 & if \quad \phi < 4 \\ \in [0, C] & if \quad \phi = 4 \\ C & if \quad \phi > 4 \end{cases} \end{aligned} \tag{3}$$

In order to have a benchmark for what would happen in a world without distributional conflict, consider the case where e_i and e_j are constrained to be zero. Then the resulting game is equivalent to a two player voluntary contribution mechanism (VCM) for a public good with the marginal private return (MPR) of $\phi/2$. There socially beneficial investment is an equilibrium if $\phi \geq 2$. Therefore, for $\phi \in (2, 4)$ the anticipated distributional fight in theory prevents cooperation that would appear if the distribution of the proceeds

[5] e_i^* and e_j^* are shorthand for $e_i^*(c_i, c_j)$ and $e_j^*(c_i, c_j)$, respectively.

were enforced without conflict by a third party or by strong property rights. We have a hold-up problem.

A vast amount of experimental studies have shown that humans to a certain extend cooperate even if the MPR is below unity as long as the marginal social return ϕ is greater than one.[6] Such a situation occurs in our case if $\phi \in (1,2)$ and if efforts are restricted to zero. There is an interesting empirical questions arising from the comparison of our strategic game to the standard VCM game. How strong do incentives have to be to induce cooperation in our model, where the proceeds from cooperation have to be fought for? Do subjects cooperate when $\phi \in (1,2)$, as they do in the normal VCM game with the equivalent marginal private return? Do subjects cooperate in the case where in the VCM with an equivalent MPR full cooperation is an equilibrium, while it is not in our game (i.e. for $\phi \in [2,4)$) with a conflict stage?

In the standard VCM with an efficiency factor that creates a social dilemma, subjects' contributions are beneficial for social welfare. This is not necessarily the case in an environment where the proceeds from cooperation will be fought over. Observe that an increase in the contribution increases the prize for the following contest and therefore the incentive to expend resources in the fight for a share of the prize. Suppose that subjects play the contest stage according to SPNE and foresee this. The following question arises: for which parameter values is the remaining reduced game still a social dilemma, in which cooperation is socially beneficial but not individually rational?

Remark 2 *If we assume that players exert equilibrium efforts* $e_i^* = e_j^* = \phi(c_i + c_j)/4$*, then the reduced game is a social dilemma whenever* $\phi \in (2,4)$.

To see this, take the individual payoff from (1) and the joint payoff from (2) and substitute in the optimal effort to obtain

$$\begin{aligned} U_i &= C + \phi(c_i + c_j)/4 - c_i \\ U_i + U_j &= 2C + \phi(c_i + c_j)/2 - c_i - c_j \end{aligned}$$

The arising reduced game is a social dilemma if

$$\begin{aligned} \frac{\partial U_i}{\partial c_i} &= \frac{\phi}{4} - 1 < 0, \text{ and} \\ \frac{\partial (U_i + U_j)}{\partial c_i} &= \frac{\phi}{2} - 1 > 0, \end{aligned}$$

[6] See Ledyard (1995) for a survey of the early literature and Chaudhuri (2011) for a recent survey of the dynamics of cooperation.

which is the case if $\phi \in (2, 4)$.

2.2 Equilibrium in the constrained case

If a player has to finance his investment and fighting effort from the same budget C, then we are in case b) from Definition 1. Solving backwards, it becomes clear that for low initial investments the constraint does not come into play and the subgame-perfect continuation follows equation (3). This is the case for player i whenever

$$C - c_i \geq \frac{\phi}{4}(c_i + c_j) \ \forall i = 1, 2, i \neq j.$$

Note that the critical player is the player who has a lower budget left after investing. If the player who invested more in the first stage has still enough funds to exert effort e^* then the other player has also enough funds left. Taking this into account and solving the inequality above results in the following Lemma.

Lemma 1 *The subgame-perfect continuation efforts are* $\left\langle \frac{\phi}{4}(c_i + c_j), \frac{\phi}{4}(c_i + c_j) \right\rangle$ *if*

$$\max_{i=1,2} c_i + \frac{\phi}{4+\phi} \min_{i=1,2} c_i \leq \frac{4C}{4+\phi}. \tag{4}$$

In a next step we establish that a player, who is constrained, prefers the maximum effort possible to any other lower effort given the effort of the opponent. Observe that the marginal benefit of increasing the effort is positive for all efforts below the best-response effort as i's objective function is concave in e_i.[7] It follows that the best response to an effort that leaves a player constrained is the maximum effort available:

$$e_i^*(e_j) = \min\left\{C - c_i, \sqrt{Ve_j} - e_j\right\}. \tag{5}$$

Further observe that only the increasing part of the best-response correspondence comes into play, as the unconstrained best-response correspondence increases up to the unconstrained equilibrium continuation at $V/4$ and greater efforts are strictly dominated. Existence of the subgame-perfect continuation is not a problem, since best-responses are continuous on the relevant compact domain $[0, V/4]$. We can now establish that the player with less resources left in a subgame-perfect continuation will always fully exhaust the remaining resources if the constraint is binding, while the player with more resources best-responds to this.[8]

[7] This is the case as $\partial^2 U_i / \partial e_i^2 = -2e_j V/(e_i + e_j)^3$.

[8] This result has been derived before by Che and Gale (1997).

Lemma 2 *If $c_i \geq c_j$ and*

$$c_i + \frac{\phi}{4+\phi} c_j \geq \frac{4C}{4+\phi},$$

then in the subgame-perfect continuation we have

$$e_i^* = C - c_i$$

and

$$e_j^* = \min \left\{ C - c_j, \sqrt{\phi(c_i + c_j)\,(C - c_i)} - (C - c_i) \right\}.$$

Proof. See appendix. ■

In a next step we show that we can rule out the existence of asymmetric pure-strategy equilibria.

Lemma 3 *For $\phi \neq 4$ no SPNE in pure strategies exists, where $c_i^* \neq c_j^*$.*

Proof. See appendix. ■

The Lemma above guarantees that we can concentrate on symmetric equilibria. We will have two different equilibria: one that corresponds to the non-cooperation equilibrium found in the unconstrained case for $\phi < 4$ and an equilibrium, where players divide their investment evenly across cooperation and fighting.

Proposition 3 *For $\phi < 4$ an equilibrium with the outcome $c_i^* = c_j^* = e_i^* = e_j^* = 0$ exists.*

Proof. See appendix. ■

We now turn to the case where players invest positive amounts. A first conjecture could be that there exist some equilibria with positive investment for $\phi > 4$. While this conjecture is correct, the condition $\phi > 4$ is not necessary.

Proposition 4 *There exists an equilibrium with the outcome $c_i^* = c_j^* = e_i^* = e_j^* = C/2$ if $\phi \geq 8/3$.*

Proof. See appendix. ■

There also exists a mixed strategy equilibrium for efficiency factors for which we have both pure-strategy equilibria. In this mixed strategy equilibrium players randomize between choosing $c_i = 0$ and $c_i = C/2$. For a player to be indifferent between the two strategies we require a specific probability μ_j with which the other player chooses $C/2$.

Proposition 5 *For $\phi \in (8/3, 4)$ there exists a mixed-strategy Nash Equilibrium, where each player chooses $c_i = C/2$ with probability*

$$\mu = \frac{4-\phi}{2(\phi-2)}$$

and zero with probability $1-\mu$.

Proof. We require player j to make player i indifferent:

$$\begin{aligned} EU_i(C/2, \mu_j, e_i^*, e_j^*) &= EU_i(0, \mu_j, e_i^*, e_j^*) \\ \mu_j \frac{C\phi}{2} + (1-\mu_j)\frac{C(4+\phi)}{8} &= \mu_j \frac{C(8+\phi)}{8} + (1-\mu_j)C \\ \rightarrow \mu_j &= \frac{4-\phi}{2(\phi-2)}. \end{aligned}$$

Symmetry ensures $\mu_i = \mu_j$. ■

Social welfare increases in the mixed-strategy equilibrium with μ, since investments are socially beneficial.[9] Expected social welfare in the Nash Equilibrium is given by

$$W_{mix} := \frac{C}{8}\left(18 + \frac{4}{\phi-2} - \phi\right). \tag{6}$$

Somewhat counter-intuitively social welfare in this equilibrium is monotonously decreasing in the efficiency of investment ϕ.

2.3 Welfare predictions

Comparing the predicted social welfare across the two different situations (constrained and unconstrained), shows that there exists an interval of the investment efficiency, where equilibrium welfare can be higher in the constrained case. For $\phi \in (8/3, 4)$ in the unconstrained case only a zero contribution equilibrium exists, while in the constrained case also equilibria exist, where players contribute half their endowment with positive probability. The expected welfare in these equilibria is greater than in the zero-contribution equilibrium. For all other parameter values of ϕ the predicted welfare is the same in both conditions. Figure 1 plots the ratio of expected welfare to the value of the endowments. Values of above one represent gains from cooperation. The solid line represents equilibria that yield the

[9] Observe that the welfare W increases with the number of players investing $C/2$, since $W(0,0) = 2C$, $W(C/2, 0) = W(0, C/2) = C(3/2 + \phi/4)$ and $W(C/2, C/2) = C\phi$.

same welfare in the constrained and unconstrained case. The dashed lines represent the higher welfare in the constrained case from the pure-strategy equilibrium (the straight increasing line) and from the mixed-strategy equilibrium (the convex and decreasing line).

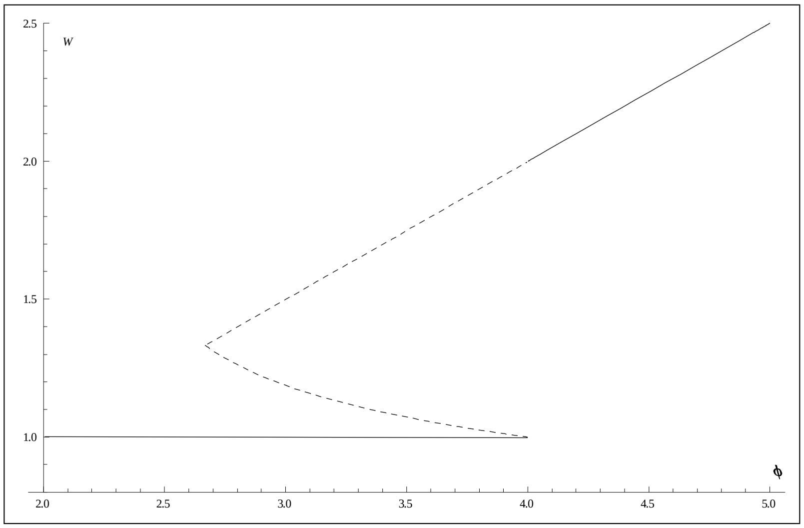

Figure 1: Welfare predictions

From public-goods experiments we know that humans regularly cooperate to a certain extent in social dilemma situations despite of the dominant strategy not to do so. In what follows we engage in a thought experiment. Assume that subjects expect and execute equilibrium play in the contest phase. Under this assumption we can check if then the contribution stage still constitutes a social dilemma. Clearly, for the constrained case with $\phi \in (8/3, 4)$ this is not the case, since there are two equilibria with positive contributions. The game has become a coordination game. [10]

For the unconstrained case things are straight-forward and we have established in Proposition 1 that the reduced game is a social dilemma for $\phi \in (2, 4)$. This implies that contributing if $\phi < 2$ is only welfare enhancing if in the second stage subjects can manage to reduce efforts below the equilibrium level. Otherwise, the increase in the value of the joint project due to an increased contribution is overcompensated by the wasted effort in the distributional contest induced by the increase in the value. In contrast,

[10] For $\phi \in (1, 8/3)$ we still have a social dilemma. However, the marginal social return of a unit of contribution only becomes positive for large contributions (i.e. when the constraints are binding).

in the case of $\phi \in (2, 4)$ an increased contribution leads to a larger increase in the value of the joint project than in the resources wasted in the contest. Therefore, contributions in this case over-all improve welfare, even if in the contest stage optimal efforts are chosen. Note that a rational and purely selfish player still does not have an incentive to contribute, as the expected private return of the contribution is negative.

3 Experimental design

Given the theoretical treatment above, four sub-cases are of major interest. First we want to test if there is a tendency for subjects to invest in the project in a case where it could damage over-all welfare. For this reason we require a treatment with $\phi < 2$, where in the unconstrained case optimal efforts wipe out more welfare than the contributions create. We choose a factor of $\phi = 1.6$.[11] We complement the treatment with unconstrained efforts by one where both contributions and efforts have to be financed by the same endowment. This will help answering the question if constraints on the war chest mitigate the problem of welfare damaging contributions. These treatments with low efficiency factors will be referred to as *unconstrained_low* and *constrained_low*.

Our second case of interest is that of a high social return to contributions. There, in the unconstrained case higher contributions are social-welfare enhancing, but not individually rational (for $\phi < 4$). Theoretically, in the constrained case with the same efficiency factor (for $\phi \in (8/3, 4)$) welfare should be weakly higher, as beyond the no-contribution equilibrium two others featuring positive contributions exist. If we take into account that subjects might be able to overcome the social dilemma in the unconstrained case, then the expected welfare ranking could be reversed, as subjects do not have to keep resources for fighting in reserve. We run two treatments with an efficiency factor of $\phi = 3$ and denote them by *unconstrained_high* and *constrained_high*. Table 1 summarises the treatments and reports the equilibrium predictions. Note that we have multiple equilibria in the *constrained_high* treatment. So we report the two different contribution and the three different effort levels that might be observed in equilibrium.

In all four treatments we set the endowment to $C = 20$. Subjects played 20 of the two-stage games each. The treatments were computerised and

[11] Note that $\phi = 1.6$ corresponds to a VCM with private return of 0.8 if subjects disregard the following contest. In two-player VCM's with a private return of 0.8 subjects contribute substantial amounts (see the control treatment in Bayer (ming)).

	unconstrained	constrained
high	$\phi = 3; c_i \in [0, 20]; e_i \geq 0$ $c_i^*, e_i^* = 0$	$\phi = 3; c_i + e_i \in [0, 20]; c_i, e_i \geq 0$ $c_i^* \in \{0, 10\}, e_i^* \in \{0, 7.5, 10\}$
low	$\phi = 1.6, c_i \in [0, 20], e_i \geq 0$ $c_i^*, e_i^* = 0$	$\phi = 1.6; c_i + e_i \in [0, 20]; c_i, e_i \geq 0$ $c_i^*, e_i^* = 0$

Table 1: Treatments

programmed in z-tree (Fischbacher, 2007).

For each treatment we ran five sessions with between 18 and 24 subjects. We employed a stranger design, i.e. after each period new groups of two were randomly determined. In two sessions per treatment the matching pool consisted of all subjects in the session. In the remaining three sessions we formed subgroups of six subjects that were randomly re-matched to each other. With the creation of the smaller matching groups we are able to obtain a reasonable number of independent observations.[12] Over all, 512 subjects participated in our experiments.[13] Subjects were recruited using ORSEE (Greiner, 2003). The participants were mainly students (undergraduate and postgraduate) of the University of Adelaide and other South Australian universities. Experimental earnings were exchanged for Australian Dollars at the end of the session. On average, subjects earned a bit more than 20 Australian Dollars (slightly below $20 US at the time of the experiments). The experiment, including the reading of the instructions and payment, took about one hour.

4 Results

In what follows we will present our main results. First, we look for treatment effects with respect to social welfare. Then we will dig deeper and identify the underlying drivers of these treatment effects.

[12] Comparing the distributions of key variables such as contributions, efforts and payoffs of the sessions with matching subgroups to those without does not yield significant differences.

[13] In the main four treatments we had 444 subjects. The remainder participated in two additional treatments that investigate, why we did not observe excessive efforts as documented in many other papers. See Section 4.2.3.

4.1 Social Welfare

In our setting the average social welfare in a treatment is given by the average profit subjects earn in this treatment. Standard theory predicts that we will observe the same welfare in three of the treatments (*unconstrained_ high*, *unconstrained_ low* and *constrained_ low)*. In all of these the unique equilibrium entails zero contributions and zero efforts with the consequence that all subjects make a profit of 20 Experimental Currency Units per period (i.e. they keep their endowment). In the remaining treatment (*constrained_ high*) besides the zero-contribution equilibrium there exist two other, more efficient equilibria. In the most efficient equilibrium subjects evenly split their endowment on contributions and efforts, which would result in a profit of 30 ECU. In the remaining mixed strategy equilibrium on average the payoff is equal to 22.5 ECU (the group welfare from Equation (6) divided by two.

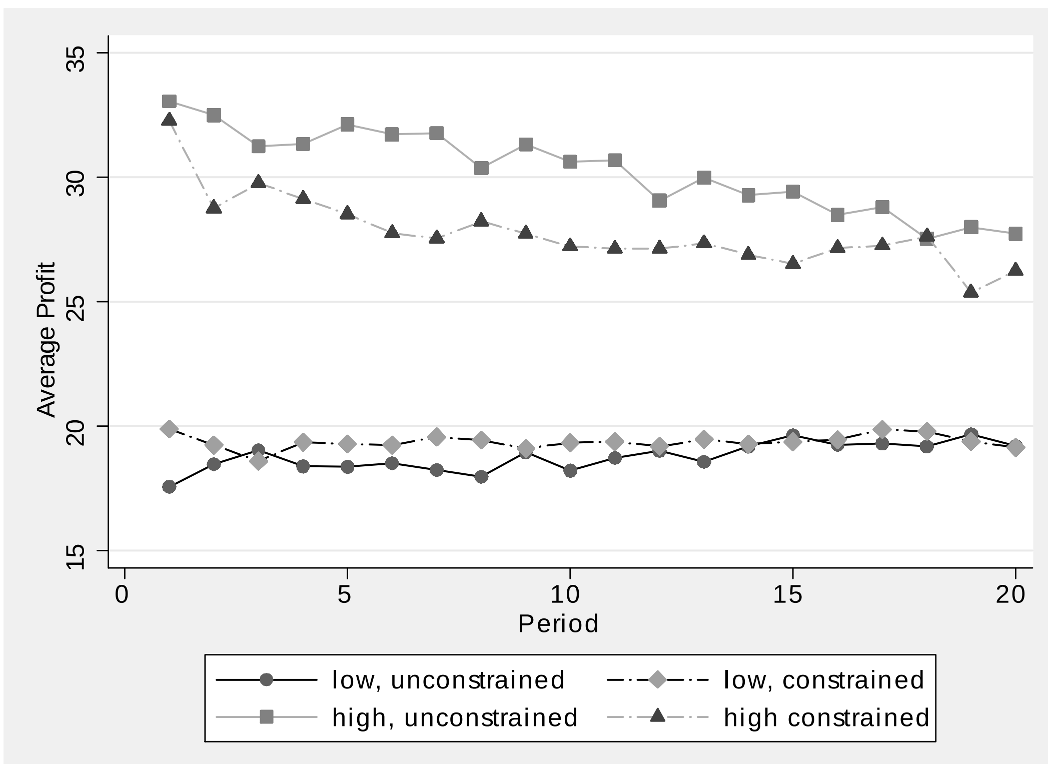

Figure 2: Average profit by treatment and period

Figure 2 plots the average profit for the different treatments across rounds and demonstrates a strong treatment effect. Individual average profits are greater in the high than in the low efficiency treatments ($p < 0.01$ for all pair-wise treatment comparisons, M-W tests on payoffs averaged over all rounds and subjects within a matching group). Within an efficiency level, subjects being constrained has differential effects on individual payoffs. Constraint subjects have lower profits compared to the unconstrained ones if the efficiency factor is high ($p < 0.06$, M-W test, two-sided). This clearly contradicts the theoretical predictions, as only in the constrained case equilibria exist with positive welfare improving investments. If the efficiency factor is low, then the constraint on efforts tends to improve profits ($p < 0.055$,M-W test, two-sided), while theory would predict no difference.[14]

Next we compare the average profit made in the treatments to the predicted profits. Table 2 shows the results from one-sided median tests on the basis of profits averaged across all individuals within an independent observation and all periods.[15] We see that subjects in the *unconstrained_low* treatment made less profit then they would have made if they had not cooperated at all as prescribed by equilibrium. The same is true for the *constrained_low* treatment. This difference is significant due to the very small variation across independent observations (the 13 independent observations all lie between 18.5 and 20.2). The quantitative deviation from equilibrium profits is small though. In the *unconstrained_high* treatment, where conditional on subgame-perfect efforts contributing improves surpluses, subjects did significantly better than in the unique non-cooperation equilibrium. Subjects were able to overcome the hold-up problem to some extent. In the *constrained_high* treatment, the profits sit somewhere between the prediction for the best equilibrium, where the endowment is equally shared between cooperative investment and fighting, and the mixed-strategy equilibrium. These results remain unaltered if we either consider only the last ten or just the last period. This shows that our findings are not driven by early rounds, where subjects might still exhibit a considerable amount of confusion.

[14]Considering that we only have 13 to 14 independent observations per treatment the results are surprisingly strong. A random-effect panel that exploits all individual variation, allows for clustering on the level of an independent observation, and controls for period effects and demographics confirms the results.

[15]It is quite tricky to come up with a valid test here, since it is unclear what an appropriate distribution under the null hypotheses would be. The median test does not make specific assumptions on the distribution but requires that values above and below the median can be observed. Moreover the test results cannot be interpreted in terms of average efficiency if the distribution is asymmetric.

Treatment	H_0	average	p-value	Remark
unc_low	profit = 20	18.78	$p < 0.01$	less efficient than predicted
con_low	profit = 20	19.38	$p < 0.01$	less efficient than predicted
unc_high	profit = 20	30.25	$p < 0.01$	more efficient than predicted
con_high	profit = 20	27.77	$p < 0.01$	more efficient than in worst equilibrium
	profit = 22.5		$p < 0.01$	more efficient than in mixed equilibrium
	profit = 30		$p < 0.01$	less efficient than in best equilibrium

Table 2: Testing efficiency differences compared to prediction

4.2 Contributions and efforts

There are two elements that drive social welfare: contributions have a positive effect and efforts impact negatively. This is the case in all treatments. While the contributions' marginal welfare improvement is greater in the treatments with a high efficiency factor, the cost of effort is the same in all treatments. However, a higher value of the group project, that is caused ceteris paribus by a greater efficiency factor, also strengthens the incentive to exert wasteful effort. So apparently, in the light of observed play being off-equilibrium, it is not clear a priori whether the efficiency differences across treatments and the deviations from the theoretical predictions are driven by contributions or efforts or a combination of both.

Figure 3 shows the decomposition of the net surplus over time in the low efficiency treatments. The circles represent the average surplus that was created from contributions. Here we consider only the net surplus creation, which means that we deduct the opportunity cost of investing. In the low efficiency treatments each unit of contribution creates 0.6 units of net surplus (i.e. $\phi - 1$). The triangles depict the average surplus wasted in the distributive contest, which is equal to average effort as effort causes a unit cost. The difference between the circles and triangles is the average welfare change caused by subjects engaging in investment and distributional contest. In the case where the triangles are above the circles the difference represents a welfare loss. When the circles are above the triangles, then we have a welfare gain compared to a subject neither investing nor fighting. We see that in both treatments the surplus creation from investment is quite similar. In both treatments the surplus created starts at a similar level and declines with time. The difference in efficiency in the two treatments (as established above) comes from the difference in resources wasted in the con-

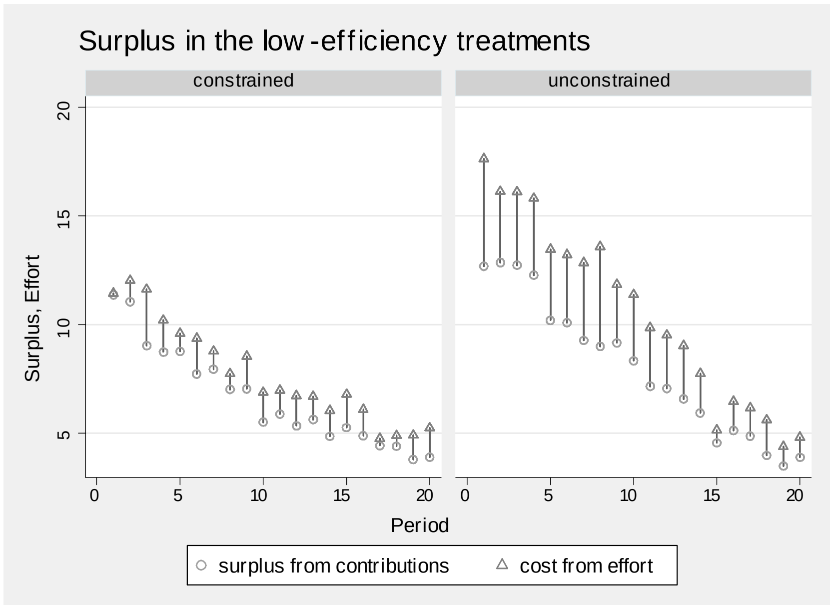

Figure 3: Net surplus in the low-efficiency treatments

test. As one might expect, the amount of resources wasted is greater in the case where there are no constraints. The welfare losses in earlier periods in the unconstrained case are driven by high efforts over-compensating for the surpluses. The gap between surpluses and efforts narrows over time, as efforts decline more strongly than surpluses. In the constrained case average surpluses are very similar to those in the unconstrained case. The slightly lower efforts are the driving force behind the higher efficiency compared to the unconstrained case in early periods.

In the high-efficiency treatments depicted in Figure 4, we observe much higher surpluses created. This is caused by both higher investments and by a higher net surplus per unit of investment (i.e. $\phi - 1 = 2$). Also, the surpluses (i.e. the contributions) do not decline sharply over time, as in the low efficiency case. Remarkably, the surpluses are very large in the unconstrained case, where standard theory would have predicted zero surpluses. In the constrained treatment, where equilibria with positive contributions exist, surpluses are lower though. Efforts follow the surpluses. Subjects use more resources in the unconstrained case, where surpluses are higher. Over-all the effect of very high surpluses in the unconstrained treatment dominates the effort effect. Therefore welfare is higher in the unconstrained

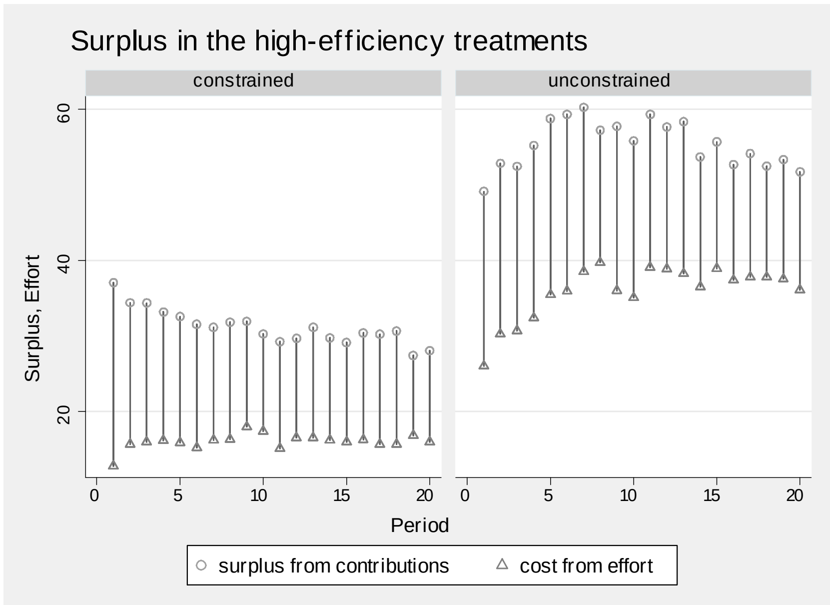

Figure 4: Net surplus in the high-efficiency treatments

case.

4.2.1 A closer look at contributions

Looking at the evolution of contributions (Figure 5) we see several interesting patterns. In both conditions (i.e. constrained and unconstrained) the contributions in the treatments with a high efficiency factor on average tend to be greater than in the corresponding treatment with a low efficiency factor. In addition, the treatments with the low efficiency factor show a downward trend, which is reminiscent to the decay of cooperation in public goods games without distributional contests. In contrast, a high efficiency factor leads to stable investments. Moreover, subjects seem to be careful not to exhaust their budget through contributions and to become defenseless in the constrained treatments. This leads to contributions being higher in the unconstrained treatments when compared to the constrained case with the same efficiency factor.

We also ran a random-effects regression with error clustering on independent observations reported in Table 3 in the Appendix, which confirms the intuition gained from the visual inspection of average contributions.

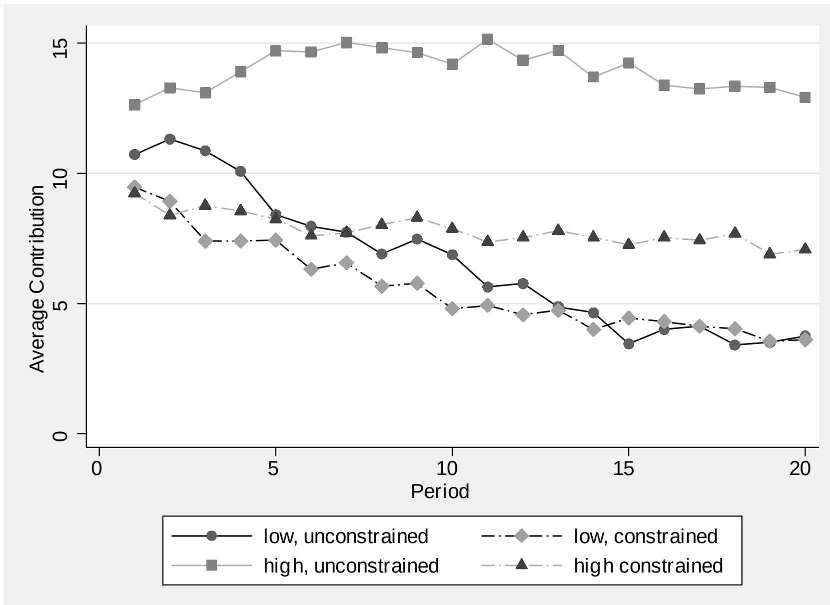

Figure 5: Average contributions over time

4.2.2 A closer look at efforts

A closer look reveals that on average subjects' efforts are remarkably close to the subgame-perfect continuation efforts. For given contribution levels subjects chose on average efforts that are close to Nash.

Figure 1 plots actual efforts against the predicted subgame-perfect efforts for the *unconstrained* treatments. We also depict a linear prediction (the dashed line). Observe that in both treatments the linear prediction is very close to the 45-degree line, which indicates that on average efforts were close to the Nash prediction. In the low-efficiency treatment the slope of the linear prediction is very close to one (0.93 with a standard error of 0.01), while it is slightly lower in the high-efficiency treatment (0.85 also with a standard error of 0.01). So on average subjects exert efforts close to those that are subgame perfect. Recall that the subgame-perfect continuation effort is exactly a quarter of the project value. In a somewhat crude statistical test based on the independent observations we take the average ratio of effort to the value of the project across all periods and subjects that form an independent observation and compare these ratios to the equilibrium ratio of 0.25 using a median test. In the low efficiency treatment there is no statistically significant difference ($p > 0.99$, two-sided), while there is a

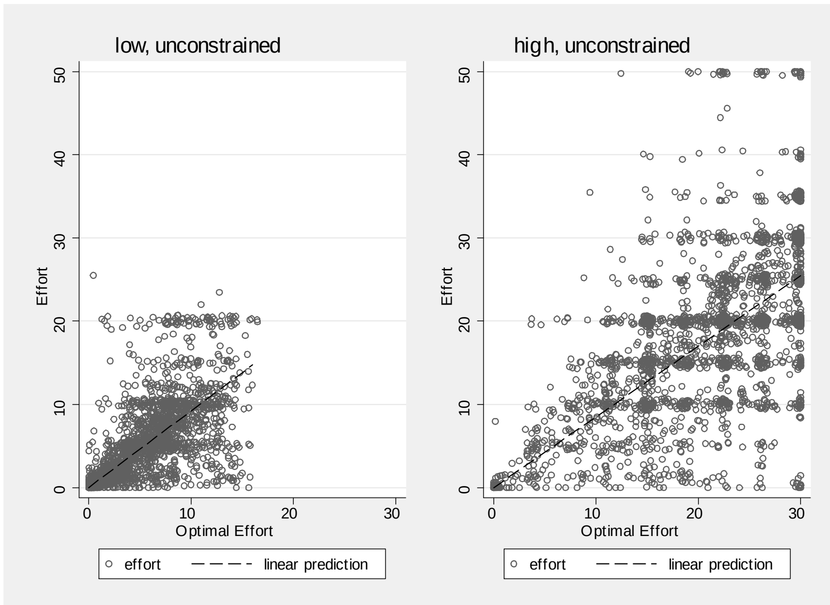

Figure 6: Actual effort vs. Nash effort in the unconstrained treatments

difference for the high efficiency treatment ($p < 0.02$, two-sided).

We obtain the same result if we use a more sophisticated econometric model. We ran a multilevel panel regression model were we regressed effort on an interaction between the value of the group project and the treatment. In addition, we took into account that there might be unobserved heterogeneity on the individual and on the independent observation level by allowing for random coefficients on both levels. The estimated fractions were 0.23 (Std Err = 0.01) in the low efficiency treatment and 0.203 (Std. Err. = 0.009) in the high-efficiency treatment. Only the fraction for the high-efficiency treatment was significantly different (i.e. lower) than the predicted quarter ($p < 0.01$). Figure 7 shows the distribution of individual slopes we estimated. While it is clustered around the optimal value (i.e. 0.25) for the low efficiency treatment, the individual ratios are slightly lower in the high efficiency treatment.

In the light of the result that we do not have over-dissipation without constraints on efforts, one might expect to observe strong under-dissipation in the case of constrained efforts. This is not the case. On average, efforts are even closer to optimal efforts in the constrained treatments than in the unconstrained. In Figure 8 we again provide a scatterplot where we plot

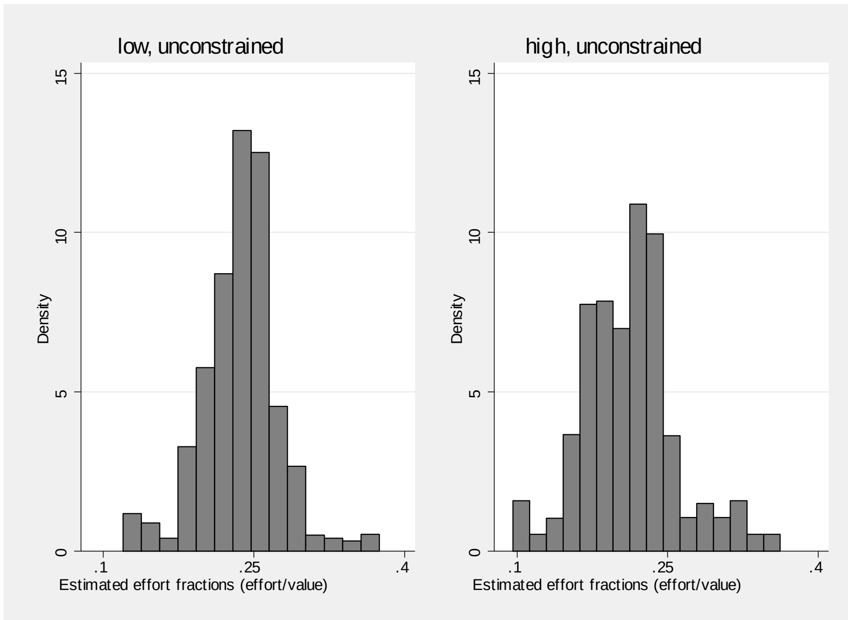

Figure 7: Estimated individual effort/value ratios

actual efforts against Nash efforts. In the case of constrained efforts we distinguish between observations, where subjects exhausted their remaining budget for effort (light grey circles) and where they did not (dark grey circles). Again, we also plot the linear prediction, which here in both cases almost coincides with the 45-degree line. This indicates that the average actual effort is extremely close to the average Nash effort. The slopes are 0.99 in the low treatment and 0.94 in the high treatment with robust standard errors (clustered on individual observations) such that only in the high efficiency treatment the slope differs significantly from unity.[16]

4.2.3 Why is there no significant over-exertion of efforts?

The observation that subjects' efforts are close to the equilibrium, if not a bit lower, are quite surprising, since most experimental studies with contests report over-exertion of efforts (for recent surveys see Sheremeta, 2013; Dechenaux et al., 2014). While many factors have been shown to influence

[16] These statistical inference results should be taken with a grain of salt. It is difficult to develop a valid statistical test for the deviation from the optimal effort in the constrained case, as the constraint truncates the distribution of possible choices in a non-trivial way.

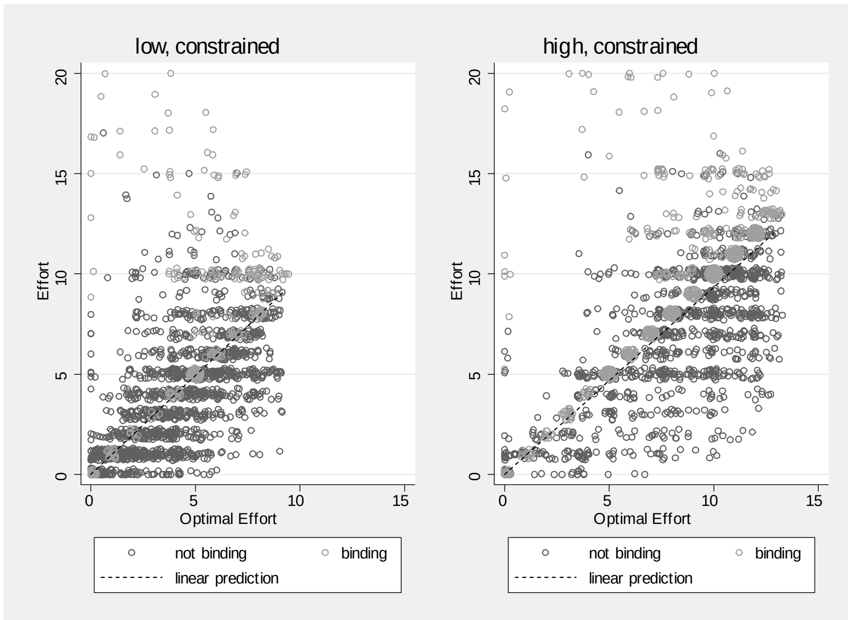

Figure 8: Actual vs. Nash efforts in the constrained treatments

the degree of over-dissipation, its existence has proven very robust. For example, groups over-dissipate more than individuals, and over-dissipation is stronger with within-group punishment opportunities (Abbink et al., 2010). The interaction of the feedback subjects receive and the nature of the contest function (sharing versus stochastic winner-takes-it-all) has a strong impact on efforts. Only in the share contest without information on the opponents actions and payoffs over-dissipation disappears in latter rounds (Fallucchi et al., 2013). Sharing contests – as in our case – yield efforts closer to Nash equilibrium than lottery contest if cost are convex (Chowdhury et al., 2014). Smaller endowments are another way to reduce over-exertion (Price and Sheremeta, 2011). Over-exertion also exists in multi-stage (Sheremeta, 2010) and asymmetric (Fonseca, 2009) contest. Allowing subjects to form alliances does not prevent excessive efforts (Ke et al., 2013). Moreover, breaking up one grand contest into smaller sub-contests (Sheremeta, 2011) or rationing the available effective effort (Faravelli and Stanca, 2012) does not solve the problem. Neither does combing the contest with another decision (Bayer and Sutter, 2009).

In our treatments with constrained effort subjects cannot over-exert efforts, whenever the effort constraint is binding. In these situations any mistakes made by subjects necessarily are those of under-exerting. Together with over-exertion in situations where the constraints do not bind, this plausibly explains near Nash play on average. The finding that there is no over-exertion on average in the unconstrained treatments is more interesting, though. In what follows, we explore potential causes specific to our design. One likely major cause is that we use a share contest, which eliminates extra utility of winning or risk preferences as drivers of excessive efforts. Since this is well documented (Shupp et al., 2013; Chowdhury et al., 2014), we explore other possible causes. We have three potential influence factors in mind. Firstly, if subjects are reciprocal then after observing contributions in the first stage they may reciprocate with lower competitiveness in the second stage. Secondly, the fact that subjects play a contribution stage before the contest might put subjects in a cooperative frame of mind, which leads to less aggressive behavior in the contests.[17] Thirdly, an important difference from other studies on contests is that we provide our subjects with a profit calculator that calculates their share of the prize, cost and their net profit for any combination of own and partner efforts they enter.[18] If bounded rationality is a major driver of over-exertion of effort then the calculator should clearly reduce efforts.[19]

Reciprocity as a major reason for lower than expected efforts can be excluded by looking more closely at the data. We use a random-coefficient model (reported in Table 4 in the Appendix) with error clustering on independent observations to estimate the determinants of the slope of the effort-prize relation. Somebody who is playing according to equilibrium should have a slope coefficient of 0.25 which should be invariant to all other variables. If subjects are reciprocal though, then the effort as a fraction of the prize should decrease if the partner was generous in the contribution stage. We use the difference in the contributions as a fraction of total contributions as a measure. This measure takes on the values one if only the other player contributed, zero if both contributed the same amount and minus one if only the person in question contributed. The coefficient on this measure capturing reciprocity is very small and not significantly different from zero.[20]

[17] Savikhin and Sheremeta (2013) found such spillovers when a cooperative and a competitive game were played simultaneously.

[18] Mago et al. (2013) is to our knowledge the only other study that used some kind of a calculator in experimental contests. There the calculator was not a profit calculator but just a calculator for the winning probability though.

[19] Lim et al. (2014) and Sheremeta (2011) show that models of bounded rationality such as Quantal Response Equilibrium or Cognitive Hierarchy predict over-exertion.

[20] For robustness we tried different measures such as dummies for having contributed

In order to assess if the existence of the contribution stage puts subjects in a more cooperative mind and leads to lower efforts, we ran an additional treatment where the subjects ($n = 30$, recruited from the same population) played only the contest stage. In order to make the contest comparable across treatments we matched every subject in this new treatment with one from the *high_unconstrained* treatment. We then let the new subject play exactly the same contests their match from the original treatment had played (with the identical prize and residual endowments). So these players played exactly the same contests as other subjects had played without ever hearing about the existence of a contribution stage. The results show that the hypothesis of a contribution stage putting subjects in a more cooperative mindset cannot be supported. The coefficients estimating the effort-value ratio in the aforementioned random-coefficient model are not significantly different across the original and the treatment without a cooperation stage. Moreover, the distributions of estimated individual slopes are not significantly different (KS test, $p > 0.62$). Furthermore, the mean slopes estimated for the two different treatments are extremely close (i.e. 0.219 vs. 0.216).

Finally, we ran a treatment (two sessions with 38 subjects from the same population) that was identical to the high-unconstrained treatment but with the profit calculator removed. With this we can test the third hypothesis which attributes overly high efforts to bounded rationality. We find that subjects indeed expend higher efforts for given prizes if the profit calculator is removed. The estimated parameter for the share of the prize invested as effort is significantly higher without the profit calculator than in the *high_unconstrained* treatment ($p < 0.05$). Also the average predicted individual fraction of the prize invested as effort (i.e. the mean slope mentioned above) is clearly higher without a profit calculator (i.e. 0.262 vs. 0.219). A KS-test rejects the null hypothesis of identically distributed individual slopes ($p < 0.001$). This shows that the profit calculator as expected reduces efforts significantly. However, the effect is quite modest and without the calculator we still do not observe excessive efforts to the extent reported in many other studies.

In summary, the lack of over-exertion of efforts is not caused by the combination of cooperative and competitive stages. Our profit calculator has been identified to cause lower efforts. The effect is not sufficiently large to explain the difference from other contest experiments. We conjecture that the main factor driving the comparatively low efforts has been the use of a

more or less than the other but never obtained a significant coefficient.

share contest instead of a lottery contest.

5 Conclusion

This paper develops a simple model of cooperation and distributive conflict and tests its predictions in the laboratory. The observed willingness of (at least some) humans to cooperate, which contradicts standard theoretical predictions, has interesting consequences in our environment. While cooperation increases social welfare in pure social dilemmas, we observe that for a low social return it is welfare damaging if a distributive contests follows. Subjects only learn over time that they are better off by not cooperating. In situations, where the social return of cooperation is high, unpredicted but observed cooperation improves welfare considerably. In both cases, with high and low social returns, the welfare effect is dampened, when cooperative investment and effort in the distributive contest have to come from the same budget. The resulting reduction in efforts in the distributional contest prevents an over-all damage of welfare in the case of low returns to cooperation. In the high return case we observe lower levels of cooperation, which leads to lower welfare gains than when efforts are unconstrained. This is in clear contrast to the theoretical prediction that welfare is expected to be weakly higher in the constraint case. This can be explained as follows. The constraint allows agents in theory to overcome part of the holdup-problem, as contributions reduce the amount of efforts left for fighting and therefore make contributing worthwhile. At the same time contributions cannot be too high as then agents would become defenseless in the contest. In the unconstrained case players are predicted by theory not to overcome their hold-up problem at all. In the experiments they do overcome the hold-up problem though. Contributions are even higher, because there is no need for keeping some of the endowment for the distributive contest.

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References

Abbink, K., J. Brandts, B. Herrmann, and H. Orzen (2010). Intergroup conflict and intra-group punishment in an experimental contest game.

American Economic Review 100(1), 420–47.

Bayer (forthcoming). Partnerships - the role of reputation and breakups. *Journal of Institutional and Theoretical Economics*.

Bayer, R.-C. and M. Sutter (2009). The excess burden of tax evasion–an experimental detection-concealment contest. *European Economic Review 53*(5), 527 – 543.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: a selective survey of the literature. *Experimental Economics 14*, 47–83.

Che, Y.-K. and I. Gale (1997). Rent dissipation when rent seekers are budget constrained. *Public Choice 92*(1/2), pp. 109–126.

Chowdhury, S. M., R. M. Sheremeta, and T. L. Turocy (2014). Overbidding and overspreading in rent-seeking experiments: Cost structure and prize allocation rules. *Games and Economic Behavior 87*(0), 224 – 238.

Collier, P. and A. Hoeffler (2004). Greed and grievance in civil war. *Oxford Economic Papers 56*(4), 563–595.

Dechenaux, E., D. Kovenock, and R. Sheremeta (2014). A survey of experimental research on contests, all-pay auctions and tournaments. *Experimental Economics forthcoming.*

Fallucchi, F., E. Renner, and M. Sefton (2013). Information feedback and contest structure in rent-seeking games. *European Economic Review 64*(0), 223 – 240.

Faravelli, M. and L. Stanca (2012). When less is more: Rationing and rent dissipation in stochastic contests. *Games and Economic Behavior 74*(1), 170 – 183.

Fischbacher, U. (2007). Z-tree - Zurich toolbox for readymade economic experiments. *Experimental Economics 10*(2), 171–178.

Fonseca, M. A. (2009). An experimental investigation of asymmetric contests. *International Journal of Industrial Organization 27*(5), 582 – 591.

Greiner, B. (2003). An online recruitment system for economic experiments. In K. Kremer and V. Macho (Eds.), *Forschung und wissenschaftliches Rechnen.* Ges. für Wiss. Datenverarbeitung.

Grossman, H. (1999). Kleptocracy and revolutions. *Oxford Economic Papers 51*(2), 267–283.

Grossman, H. I. (1991). A general equilibrium model of insurrections. *American Economic Review 81*(4), 912 – 921.

Grossman, H. I. and M. Kim (1995). Swords or plowshares? a theory of the security of claims to property. *Journal of Political Economy 103*(6), pp. 1275–1288.

Hirshleifer, J. (2001). *The Dark Side of the Force: Economic Foundations of Conflict Theory*. Cambridge University Press.

Ke, C., K. A. Konrad, and F. Morath (2013). Brothers in arms – an experiment on the alliance puzzle. *Games and Economic Behavior 77*(1), 61 – 76.

Kimbrough, E. O. and R. M. Sheremeta (2013). Side-payments and the costs of conflict. *International Journal of Industrial Organization 31*(3), 278 – 286. Tournaments, Contests and Relative Performance Evaluation.

Kimbrough, E. O. and R. M. Sheremeta (2014). Why can't we be friends? entitlements and the costs of conflict. *Journal of Peace Research 51*(4), 487–500.

Kimbrough, E. O., R. M. Sheremeta, and T. W. Shields (2014). When parity promotes peace: Resolving conflict between asymmetric agents. *Journal of Economic Behavior & Organization 99*(0), 96 – 108.

Ledyard, J. O. (1995). Public goods: A survey of experimental research. In J. H. Kagel and A. E. Roth (Eds.), *The Handbook of Experimental Economics*. New Jersey: Princeton University Press.

Lim, W., A. Matros, and T. L. Turocy (2014). Bounded rationality and group size in tullock contests: Experimental evidence. *Journal of Economic Behavior & Organization 99*(0), 155 – 167.

Mago, S. D., R. M. Sheremeta, and A. Yates (2013). Best-of-three contest experiments: Strategic versus psychological momentum. *International Journal of Industrial Organization 31*(3), 287 – 296. Tournaments, Contests and Relative Performance Evaluation.

Price, C. R. and R. M. Sheremeta (2011). Endowment effects in contests. *Economics Letters 111*(3), 217 – 219.

Sambanis, N. and P. Collier (Eds.) (2005a). *Understanding Civil War (Volume 1: Africa)*. The World Bank.

Sambanis, N. and P. Collier (Eds.) (2005b). *Understanding Civil War (Volume 2: Europe, Central Asia, & Other Regions)*. The World Bank.

Savikhin, A. C. and R. M. Sheremeta (2013). Simultaneous decision-making in competitive and cooperative environments. *Economic Inquiry 51*(2), 1311–1323.

Sheremeta, R. M. (2010). Experimental comparison of multi-stage and one-stage contests. *Games and Economic Behavior 68*(2), 731 – 747.

Sheremeta, R. M. (2011). Contest design: An experimental investigation. *Economic Inquiry 49*(2), 573 – 590.

Sheremeta, R. M. (2013). Overbidding and heterogeneous behavior in contest experiments. *Journal of Economic Surveys 27*(3), 491–514.

Shupp, R., R. M. Sheremeta, D. Schmidt, and J. Walker (2013). Resource allocation contests: Experimental evidence. *Journal of Economic Psychology 39*(0), 257 – 267.

Tullock, G. (1980). Efficient rent seeking. In J. M. Buchanan, R. T. Tollison, and G. Tullock (Eds.), *Toward a Theory of the Rent-Seeking Society*. Texas A&M University Press.

A Some proofs

A.1 Lemma 2

Proof. Suppose that $e_i = C - c_i$, then e_j^* from above immediately follows from (5). It remains to be checked if $e_i^* = C - c_i$ is a best response to this. It suffices to show that the unrestricted best response to e_j^* is greater than $C - c_i$. Denote the unrestricted best response as BR. Then note that

$$BR(e_j) \geq e_j \text{ if } e_j \leq V/4,$$

since

$$\left.\frac{\partial EU_i(e_i, e_j)}{\partial e_i}\right|_{e_i=e_j} = \frac{V}{4e_j} - 1 \geq 0 \text{ if } e_j \leq V/4.$$

It follows that if $e_j^* = C - c_j$ then $BR(e_j^*) \geq C - c_j \geq C - c_i \rightarrow e_i^* = C - c_i$. It remains to check the case of $e_j^* = \sqrt{\phi(c_i + c_j)(C - c_i)} - (C - c_i)$.Note that for player i to be constrained we at least require $V/4 \geq C - c_i$, which implies that

$$\begin{aligned} e_j^* &\geq \sqrt{4(C - c_i)(C - c_i)} - (C - c_i) \\ &\geq (C - c_i). \end{aligned}$$

It follows that if $e_j^* = \sqrt{\phi(c_i + c_j)(C - c_i)} - (C - c_i)$, then $BR(e_j^*) \geq C - c_i \rightarrow e_i^* = C - c_i$. ■

A.2 Lemma 3

Proof. First observe, that for

$$\max_{i=1,2} c_i + \frac{\phi}{4+\phi} \min_{i=1,2} c_i \leq \frac{4C}{4+\phi}$$

we have

$$\frac{\partial}{\partial c_i} EU_i(c_i, c_j, e_i^*, e_j^*) = \frac{\partial}{\partial c_j} EU_j(c_j, c_i, e_j^*, e_i^*) = \frac{\phi}{4} - 1.$$

which implies that for $\phi < 4$ only $c_i = c_j = 0$ and for $\phi > 4$ $c_i = c_j = 2C/(2 + \phi)$ are equilibrium candidates. So in the unconstrained region all equilibria have to be symmetric.

Next consider the situation, where one player is constrained, while the other is not. Without loss of generality assume $c_i > c_j$. Then we can write the profit of the constrained player i as

$$EU_i(c_i, c_j, e_i^*, e_j^*) = \phi(c_i + c_j) \frac{C - c_i}{C - c_i + e_j^*}.$$

Substituting e_j^* as calculated in (5) into the equation above yields

$$EU_i(c_i, c_j, e_i^*, e_j^*) = \sqrt{\phi(C - c_i)(c_i + c_j)}.$$

The marginal expected payoff change $\partial EU_i(c_i, c_j, e_i^*, e_j^*)/\partial c_i$ has the same sign as

$$C - 2c_i - c_j,$$

which implies that the only equilibrium candidate is given by

$$c_i = \frac{C - c_j}{2}. \tag{7}$$

The payoff of the unconstrained player j is given by

$$\begin{aligned} EU_i(c_i, c_j, e_i^*, e_j^*) &= \phi\,(c_i + c_j)\,\frac{e_j^*}{C - c_i + e_j^*} - c_i - e_j^* \\ &= C + c_i(\phi - 2) + c_j\phi - 2C - \sqrt{\phi\,(C - c_i)\,(c_i + c_j)} \end{aligned}$$

with

$$\frac{\partial}{\partial c_i} EU_i(c_i, c_j, e_i^*, e_j^*) = \phi - \sqrt{\phi\frac{C - c_i}{c_i + c_j}},$$

which has a unique critical point at

$$c_j = \frac{C - c_i}{\phi} - c_i. \tag{8}$$

Since Equations (7) and (8) are not consistent with each other we can rule out an asymmetric equilibrium with one constrained player.

It remains to be checked if an asymmetric equilibrium with two constrained players is possible. The payoff of a constrained player (conditional on the other player also being constrained) is given by

$$EU_i(c_i, c_j, e_i^*, e_j^*) = \phi\,(c_i + c_j)\,\frac{C - c_i}{C - c_i + C - c_j}.$$

The first-order condition for a best response conditional on both players being constrained yields:

$$\begin{aligned} \frac{\partial}{\partial c_i} EU_i(c_i, c_j, e_i^*, e_j^*) &= \frac{\phi\left(2C\,(2c_i + c_j) - 2C^2 - (c_i + c_j)^2\right)}{2C - c_i - c_j} = 0 \\ \rightarrow c_i^*(c_j) &= 2C - c_j - \sqrt{2C\,(C - c_j)} \end{aligned} \tag{9}$$

Checking the curvature shows that for a potential local maximum (for a choice of c_i) we require:

$$\frac{\partial^2}{\partial c_i^2} EU_i(c_i, c_j, e_i^*, e_j^*) = \frac{4C(C - c_j)\phi}{(c_i + c_j - 2C)^3} \le 0,$$

which is satisfied for interior c_i and c_j.

Taking (9) and subtracting the corresponding first-order condition for player j yields

$$\begin{aligned} \sqrt{2C\,(C - c_i)} - \sqrt{2C\,(C - c_j)} &= 0 \\ \rightarrow c_i &= c_j, \end{aligned}$$

which concludes the proof. ∎

A.3 Proposition 3

Proof. We can write the profit of player i depending on c_i for player j choosing $c_j = 0$ and both players following the subgame perfect continuation after investments as,

$$EU_i(c_i, 0, e_i^*, e_j^*) = \begin{cases} C + \frac{\phi c_i}{4} - c_i & if \quad c_i < \frac{4C}{4+\phi} \\ \sqrt{\phi c_i (C - c_i)} & if \quad c_i \geq \frac{4C}{4+\phi} \end{cases}$$

First observe that the payoff is continuous at $c_i = \frac{4C}{4+\phi}$. Then since the payoff is decreasing for $c_i < \frac{4C}{4+\phi}$ and $\phi < 4$, we have

$$EU_i(0, 0, e_i^*, e_j^*) > EU_i(c_i, 0, e_i^*, e_j^*) \text{ if } c_i \leq \frac{4C}{4+\phi}.$$

Now observe that for $c_i > \frac{4C}{4+\phi}$

$$\frac{\partial}{\partial c_i} EU_i(c_i, 0, e_i^*, e_j^*) < 0 \text{ if } c_i > C/2$$

and that

$$c_i > \frac{4C}{4+\phi} \rightarrow c_i > C/2 \text{ if } \phi < 4,$$

which implies that there is no profitable deviation from $c_i^* = 0$ if $c_j = 0$. ■

A.4 Proposition 4

Proof. In any symmetric equilibrium either both players are constrained or they are both unconstrained. Taking the first-order condition for the constrained case from (9) and setting $c_j = c_i$ in order to restrict attention to symmetric equilibria yields

$$c_i = c_j = C/2.$$

So the only candidate for a constrained equilibrium outcome is $c_i^* = c_j^* = e_i^* = e_j^* = C/2$ with individuals payoffs being

$$EU_i(c_i^*, c_j^*, e_i^*, e_j^*) = \frac{\phi C}{2}.$$

Now suppose that player j chooses $c_j = C/2$ and $e_j^*(c_i, C/2)$.Then depending on the choice of i three different continuations are possible. First, both players remain constrained and reply with $e_i^* = C - c_i$, $e_j^* = C - c_j$. A deviation to an investment that does not remove the constraint for the second stage is never profitable. This follows form the first and second-order condition in the proof for Lemma (3). Second i reduces c_i such that he becomes unconstrained, while j remains constrained. This is the case for

$$C\frac{4-\phi}{2\phi} \in \left(C\frac{4-\phi}{2\phi}, C\frac{8-\phi}{2\left(4+\phi\right)}\right).$$

The continuation is $e_i^*(c_i, C/2) = \sqrt{C/2(C/2+c_i)\phi} - C/2$ and $e_j^*(C/2, c_i) = C/2$,which yields the payoff

$$EU_i(c_i, C/2, e_i^*, e_j^*) = C(3+\phi)/2 + c_i(\phi - 1) - \sqrt{C(C+2c_i)\phi}$$

Deviating marginally upwards from a given c_i yields the change in profit of

$$\frac{\partial}{\partial c_i} EU_i(c_i, C/2, e_i^*, e_j^*) = \phi - 1 - \sqrt{\frac{\phi C}{C+2c_i}}.$$

Note that the change increases in c_i, which allows us to bound this change in profit from below by setting $c_i = 0$. The lower bound then becomes

$$\phi - 1 - \sqrt{\phi} > 0 \text{ if } \phi > 8/3.$$

Therefore (and since the payoff is continuous at $c_i = \frac{C(8-\phi)}{2(4+\phi)}$) a deviation from $c_i = C/2$ towards a lower investment that removes the own constraint only is not profitable.

The third range of c_i that leads to a particular continuation is

$$c_i \leq C\frac{4-\phi}{2\phi},$$

where the constraints of both players are relaxed. The payoff of i is given by

$$EU_i(c_i, C/2, e_i^*, e_j^*) = C + \frac{(c_i + C/2)\,\phi}{4} - c_i$$

which is increasing for $\phi \geq 4$, which implies (as EU_i is continuous at $c = C\left(4-\phi\right)/2\phi$,) that for $\phi \geq 4$ the claimed equilibrium exists. For $\phi < 4$ the maximum payoff conditional on c_i removing the constraints for both plays is at $c_i = 0$, which requires

$$\begin{aligned} EU_i(C/2, C/2, e_i^*, e_j^*) - EU_i(0, C/2, e_i^*, e_j^*) &\geq 0 \text{ or} \\ \frac{C\phi}{2} - \left(C + \frac{C\phi}{8}\right) &> 0 \\ \rightarrow \phi &> 8/3 \end{aligned}$$

for the claimed equilibrium to exist. ■

B Regression tables

	contribution
Treatment (base low, unconstraint)	
low, constraint	-1.102
	(-1.82)
high, unconstraint	3.800^{***}
	(4.77)
high, constraint	-2.030^{**}
	(-2.64)
Low_phi x period	-0.372^{***}
	(-14.99)
High_phi x period	-0.0502
	(-1.42)
Constant	10.74^{***}
	(14.97)
Age, maths, gender, study dummies	Yes
N	8880
LR-test for random intercept vs. OLS	$p < 0.001$

t statistics in parentheses

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 3: Panel regression for contributions

	effort
Treatment interacted with prize value, low is base	
value	0.220***
	(13.21)
high x value	−0.029**
	(−2.65)
high, no calculator x value	0.029
	(0.96)
high, contest only x value	0.017
	(−0.91)
Relative contributions interacted with value	
Δ-contribution x value	0.007
	(1.15)
Age, maths, gender, study dummies x value	*Yes*
N	6112

z statistics in parentheses

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 4: Random coefficient model for efforts with error clustering on independent observations

C Sample Instructions

Instructions

Welcome to the experiment! Before we start, please read the instructions carefully.

During the experiment, your earnings will be calculated in points rather than Dollars. Points are converted to Dollars at the following exchange rate at the end of the session to determine your payment:

$$70\ Points = AUD\ 1.00$$

You will be paid in cash immediately after the experiment. You are not allowed to communicate with other participants during the experiment. If you have any questions, please raise your hand and we will attend to you individually. Failure to comply with the outlined rules will result in exclusion from the experiment and you will forfeit your payment.

Summary

After being grouped with a person who is randomly chosen by a computer, you will play a two-stage game described in the experiment section below. The game consists of two recurring stages. Both players' task is to decide how much to invest in a group project in the first stage. Once the project is completed both players' task, in the second stage, is to choose how much effort they would like to invest in an attempt to acquire a share of the group investment. How much effort each player puts in determines how the proceeds get split between both players.

The experiment

In what follows we will refer to the person you are playing with as your 'group member'. Both of you will be making investment and effort decisions as follows

Investment stage

On the following page is a screen shot to familiarize you with how the investment stage will appear on your screen

Your task is to divide your endowment (20 points) between what you keep for yourself and what you invest in a group project. The other group member has to do the same by choosing their investment at the same time as you.

The value of the group project depends on your investment and the investment of the other group member.

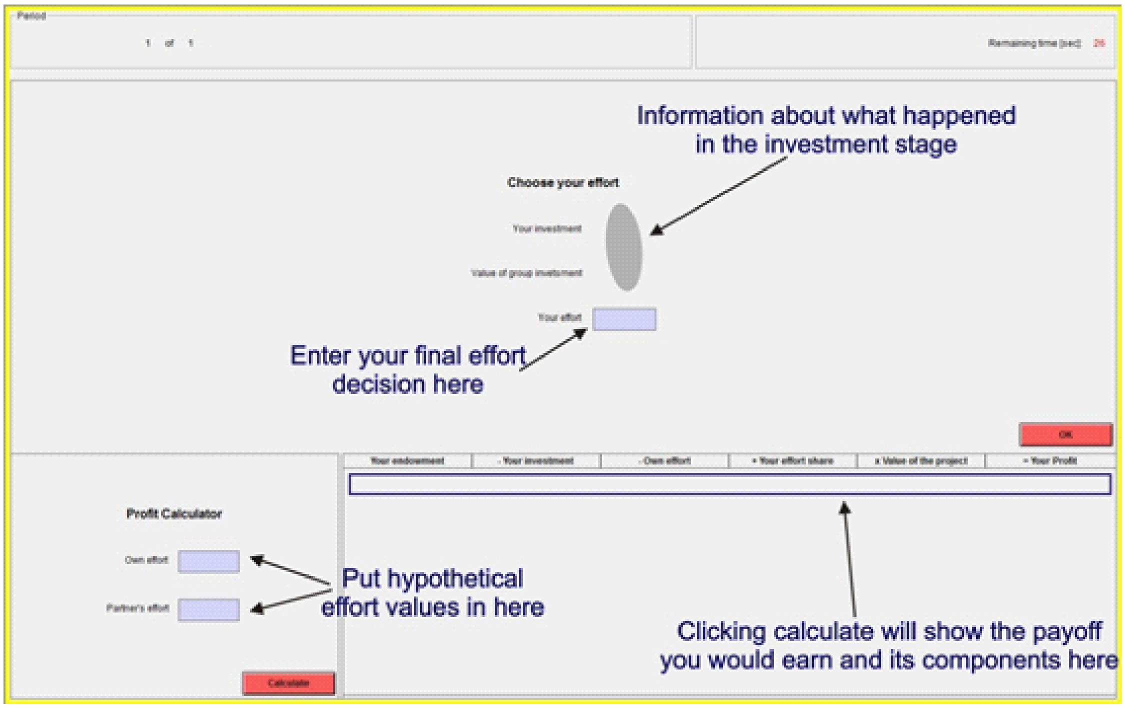
Once your investment has been made, you will be notified how much you and the other group member have individually invested in the project. The sum of your investments will be multiplied by 3 and that will be the total value of the project for that round. This means that in every round:

Value of the project = 3 x (*your investment* + *other group member's investment*)

This concludes Stage A.

Distribution stage:

The following is a screen shot to familiarize you with what the distribution or effort stage will look like on your screen:



In this stage of the experiment, your task is to determine an amount of effort that you would like to invest in order to acquire a share of the group project. Your group member has to do the same.

The more effort you put in for a given level of the other group member's effort, the larger will be your share of the project, however, the higher will be your effort cost. On the other hand, the smaller your investment of effort is for the given effort of your group member, the smaller will be your share of the project, however, the effort cost you incur will also be low. The same is true for the other group member.

As a guide, on the back of these instructions is a table attached which represents values of percentage share of the project that you can expect to get for any given values of your own and your group member's effort.

In addition, you will be provided with a profit calculator on your screen (as visible in the screen shot above) which you can use to calculate what your expected profit will be for any combination of your own and the other group member's effort input.

Please note that the profit calculator is there only for your help. It does not affect your final profit in any way. You can play around with it using different values of effort for yourself and the other group member. You can then make your decision about what would be the optimal level of effort for you to put in.

Your payoff

The total income you earn will be the sum of two parts:

1. Points that you keep (endowment - investment)
2. Your income from the group investment project.

Therefore, your total payoff at the end of each round is calculated and recorded as follows:

Profit = (*endowment* - *investment*) + *your share of the group project* - *your effort*

The other group member's income is calculated in the same way.

This process will continue until 24 rounds have been played. In each round you will be required to make two choices (investment into group project and effort to acquire a share of the project). After the 24th round your total profit will be recorded and you will be paid in cash.

The following table represents percentage share of the group project that you can expect to get for a given combination of your effort and your partner's effort. For example, if your effort input is 1 and your partner invests effort equal to 4, then you will get 20% of the group investment project. Note that your effort share (%) is calculated as follows:

$$\text{your effort} = \frac{\text{your effort}}{(\text{your effort} + \text{other group member'seffort})} \times 100$$

Other group member's effort

Your effort

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1	100.0%	50.0%	33.3%	25.0%	20.0%	16.7%	14.3%	12.5%	11.1%	10.0%	9.1%	8.3%	7.7%	7.1%	6.7%	6.3%	5.9%	5.6%	5.3%	5.0%	4.8%
2	100.0%	66.7%	50.0%	40.0%	33.3%	28.6%	25.0%	22.2%	20.0%	18.2%	16.7%	15.4%	14.3%	13.3%	12.5%	11.8%	11.1%	10.5%	10.0%	9.5%	9.1%
3	100.0%	75.0%	60.0%	50.0%	42.9%	37.5%	33.3%	30.0%	27.3%	25.0%	23.1%	21.4%	20.0%	18.8%	17.6%	16.7%	15.8%	15.0%	14.3%	13.6%	13.0%
4	100.0%	80.0%	66.7%	57.1%	50.0%	44.4%	40.0%	36.4%	33.3%	30.8%	28.6%	26.7%	25.0%	23.5%	22.2%	21.1%	20.0%	19.0%	18.2%	17.4%	16.7%
5	100.0%	83.3%	71.4%	62.5%	55.6%	50.0%	45.5%	41.7%	38.5%	35.7%	33.3%	31.3%	29.4%	27.8%	26.3%	25.0%	23.8%	22.7%	21.7%	20.8%	20.0%
6	100.0%	85.7%	75.0%	66.7%	60.0%	54.5%	50.0%	46.2%	42.9%	40.0%	37.5%	35.3%	33.3%	31.6%	30.0%	28.6%	27.3%	26.1%	25.0%	24.0%	23.1%
7	100.0%	87.5%	77.8%	70.0%	63.6%	53.5%	53.8%	50.0%	46.7%	43.8%	41.2%	38.9%	36.8%	35.0%	33.3%	31.8%	30.4%	29.2%	28.0%	26.9%	25.9%
8	100.0%	88.9%	80.0%	72.7%	66.7%	61.5%	57.1%	53.3%	50.0%	47.1%	44.4%	42.1%	40.0%	38.1%	36.4%	34.8%	33.3%	32.0%	30.8%	29.6%	28.6%
9	100.0%	90.0%	81.8%	75.0%	69.2%	64.3%	60.0%	56.3%	52.9%	50.0%	47.4%	45.0%	42.9%	40.9%	39.1%	37.5%	36.0%	34.6%	33.3%	32.1%	31.0%
10	100.0%	90.9%	83.3%	76.9%	71.4%	66.7%	62.5%	58.8%	55.6%	52.6%	50.0%	47.6%	45.5%	43.5%	41.7%	40.0%	38.5%	37.0%	35.7%	34.5%	33.3%
11	100.0%	91.7%	84.6%	78.6%	73.3%	68.8%	64.7%	61.1%	57.9%	55.0%	52.4%	50.0%	47.8%	45.8%	44.0%	42.3%	40.7%	39.3%	37.9%	36.7%	35.5%
12	100.0%	92.3%	85.7%	80.0%	75.0%	70.6%	66.7%	63.2%	99.1%	57.1%	54.5%	52.2%	50.0%	48.0%	46.2%	44.4%	42.9%	41.4%	40.0%	38.7%	37.5%
13	100.0%	92.9%	86.7%	81.3%	76.5%	72.2%	68.4%	65.0%	98.5%	59.1%	56.5%	54.2%	52.0%	50.0%	48.1%	46.4%	44.8%	43.3%	41.9%	40.6%	39.4%
14	100.0%	93.3%	87.5%	82.4%	77.8%	73.7%	70.0%	66.7%	98.1%	60.9%	58.3%	56.0%	53.8%	51.9%	50.0%	48.3%	46.7%	45.2%	43.8%	42.4%	41.2%
15	100.0%	93.8%	88.2%	83.3%	78.9%	75.0%	71.4%	68.2%	97.8%	62.5%	60.0%	57.7%	55.6%	53.6%	51.7%	50.0%	48.4%	46.9%	45.5%	44.1%	42.9%
16	100.0%	94.1%	88.9%	84.2%	80.0%	76.2%	72.7%	69.6%	97.7%	64.0%	61.5%	59.3%	57.1%	55.2%	53.3%	51.6%	50.0%	48.5%	47.1%	45.7%	44.4%
17	100.0%	94.4%	89.5%	85.0%	81.0%	77.3%	73.9%	70.8%	97.5%	65.4%	63.0%	60.7%	58.6%	56.7%	54.8%	53.1%	51.5%	50.0%	48.6%	47.2%	45.9%
18	100.0%	94.7%	90.0%	85.7%	81.8%	78.3%	75.0%	72.0%	97.5%	66.7%	64.3%	62.1%	60.0%	58.1%	56.3%	54.5%	52.9%	51.4%	50.0%	48.6%	47.4%
19	100.0%	95%	90.5%	86.4%	82.6%	79.2%	76.0%	73.1%	97.4%	67.9%	65.5%	63.3%	61.3%	59.4%	57.6%	55.9%	54.3%	52.8%	51.4%	50.0%	48.7%
20	100.0%	95.2%	90.9%	87.0%	83.3%	80.0%	76.9%	74.1%	97.4%	69.0%	66.7%	64.5%	62.5%	60.6%	58.8%	57.1%	55.6%	54.1%	52.6%	51.3%	50.0%