Effect of communication in heterogeneous group contests with incomplete information: An experimental analysis

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Abstract

Costless pre-play communication has been shown to effectively facilitate within-group coordination. This study examines how behavior in inter-group contests is altered when players can communicate with in the group as well as with the opponent group through cost less non-binding messages both under complete and incomplete information. We model a Tullock contest where there are two possible types of groups that are heterogeneous in the incentives they face, and players only know the probability their opponent is a particular group type. Then in the lab experiment, we test our results and investigate the group behavior under communication protocol. We also compare results between complete information and incomplete information. For cost and value treatment, we find that communication in the form of cheap-talk can significantly improve the performance of groups. The communication helps to mitigate wasteful rent seeking problem as well, thus making the contests more efficient from the organizers' perspective. Our experiment provides an environment where inter group communication foster cooperation under incomplete information but damages cooperation under complete information. To our best knowledge, this investigation is probably the first study of group contests with incomplete information using the cheap talk communication.

JEL Classification: C70, C91, C92, D70, D82

Keywords— group conflict, heterogeneous contests; incomplete information; between-group competition, Coordination, Communication, Experiment, Cheap-talk

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1 Introduction

Inter group conflict often taking the form of group contests is prevalent in numerous biological, social and economic situations, and has been described to be an important problem for this century [11, 44]. In international relations, conflict between nations [58] and in biology, conflict among different groups or species of animals for survival [70] may be described as group contests. In economics, group contests have been particularly used when studying the rent-seeking behaviour associated with political lobbying by special interest groups or patent and R&D competition among firms [36, 51]. Accordingly, group contests may describe a typical political lobbying situation where lobbyists representing various businesses or organizations incur expenditure in order to increase the likelihood of the organizations they represent of being selected to do business with the government. Similarly, organizations frequently incur expenditure in competing against others in patent or R&D races. Though the original contest framework is in terms of individuals competing over a prize [53, 83], it has been extended without loss of generality to competing groups by several studies [78]. The main difference between contests between individuals and groups is the aggregation rule used to determine group effort from individual effort. Group effort can be computed as the sum of effort of group members [50]. However it may also be computed as a "best shot" game where the highest individual effort in a group is designated the group effort [31] or the weakest link game, where the lowest individual effort is designated the group effort [23, 31]. See [36, 52, 78] for a comprehensive reviews of theories pertaining to contests.

As real world data from contests which may sometimes constitute borderline illegal activities is sensitive and hard to source, laboratory experiments have been very useful in exploring whether theory predictions in contests are adhered to by human players ([36, 78]). The first laboratory experiments in group contests are by [15, 69], and use an intergroup public goods or IPG game.[40, 61, 84] study group contests where group effort or contribution is simply aggregated efforts of group members. According to a comprehensive survey of group contest experiments by [78], a common feature of competitive coordination games among groups is that the effort put in by agents far exceeds the Nash equilibrium effort level leading to significant welfare losses. In laboratory coordination games with Pareto ranked equilibria, non-binding preplay communication (cheap talk) has been seen to increase efficiency [16, 25, 26, 34, 37]. [85] for instance, shows that pre-play communication increases effectiveness in coordination games. Even when they contain little information, cost less nonbinding communications, according to [9], can hasten convergence to the Pareto-efficient equilibrium. As many economic interactions particularly in development contexts can be modeled as coordination games, this result appears to have a very significant implications for designing policies that increase efficiency and social welfare. This broad inference, though, might be deceptive. In competitive coordination games like rent-seeking competitions, [21, 24] pose an important counter-example and demonstrate that intra-group communication enhances coordination but leads to more aggressive effort on the part of group members making effort levels further inefficient.

With a few notable exceptions, the literature on group contests (reviewed in [46, 52, 78] refers to even contests, i.e.- homogeneity in attributes of players within and between groups which are not heterogeneous in terms of attributes like costs, returns or probability of winning and number of group members. In such contests, certain firms or agents may have advantages or disadvantages vis-a-vis their competitors. The potential source of such advantages may be abilities or capacities of individuals in the group or their endowments. For example, the scope of exerting more effort may give companies performing R&D an advantage over competitors who have fewer resources in terms of trained personnel or find it more expensive to recruit well-trained individuals. Additionally, some organizations better able to use incentives to encourage members to take desirable actions,

which raises marginal returns from effort. [8] experimentally examines a Tullock lottery contest [83] between groups that differ in either the probability of winning or effort cost. She finds that with inter-group heterogeneity[1], advantaged players contribute relatively more effort.

Furthermore, the literature focuses on models of complete information whereas it is often likely for agents of a group or organization not to have full information related to the productivity or endowment of a competing group. To our knowledge [86] is the only experimental study that examines group behaviour in uneven contests under incomplete information. Like [8] they use a Tullock rent seeking contest and find that incomplete information increases effort in uneven contests with either cost or value heterogeneity. However, incomplete information does not alter average effort in even contests. Consistent with standard theory of behaviour in contests, they obtain that group-level effort is higher for advantaged groups, when the source of the advantage is either a lower cost-of-effort or a higher prize value. Attention to the group conflicts starts from the work of . Based on the concept of standard [83] model ad following [50] ,the work of [50] explains the intra as well as inter group conflict. Their findings show that only the prize valuation of the individuals determine the group effort level and the group size[2] plays no important role on the determination. [3]

In this research, we use theory and laboratory experiments to investigate how cheap talk communication affects effort provision in contests between groups that are heterogeneous in terms of effort cost and valuation of the prize in complete and incomplete information environments. We model a Tullock type rent seeking contest between two competing groups. Players within a group are assumed to be homogeneous. But the two competing groups can be heterogeneous in terms of the unit effort cost and valuation of the prize. These variables are binary and can either be of the high or low type and under complete information, players are aware of the cost or valuation for their own group as well as that of others. However, in our incomplete information treatments, they are only aware of the likelihood that their opponent belongs to a specific group type. In this way we incorporate value or cost asymmetry and incomplete information in our theoretical model of a group contest. We test the impact of unenforceable preplay communication by allowing participants in some of our sessions to communicate in a non-binding way with each other in our laboratory experiment. In our 2 X 2 experimental set up, we systematically vary whether teams have full or incomplete knowledge of their opponent's type and whether or not the individuals have an opportunity to engage in cheap talk via a chat room interface. In all our multiperiod experimental sessions, half the periods have cost heterogeneity while the other half have value heterogeneity. To our knowledge we are the first study to examine the role of pre-play cheap talk communication in uneven contests under incomplete information. The next sub-section surveys the literature pertinent to our theoretical exercise.

[1] [79] for detailed survey on behavior and [77] for heterogeneity and overbidding.

[2] Most common problem in group contests is the problem of free riding. But increasing group size gives no advantage to generate more group effort. The reason is as follows: increasing group size results in more free riding among the group members which in turns makes the larger group equivalent to the smaller group with respect to the contests environment. ([52], [68]). Similar argument using player's type heterogeneity is also put forward by [20].

[3] The case of heterogeneity in the contests structure is first considered by [3], [4] He considers heterogeneity within the group members with respect to the valuation of prize only. Under this circumstances, only the highest valuation player exerts positive effort while others free ride This is a well documented result in literature irrespective of the form of the contests success function ([5],[67])
Under the weakest link contests structure , this free riding problem disappears ([56]). Group contests for providing public goods with linear cost function is analyzed by [4] . In this set up, given the linearity of the cost function , the only contributor from each group is the most efficient player. But for public group contests with strictly convex cost function increases the aggregate group effort level [72].

2 Theoretical set up

Our theoretical set up follows the Tullock's rent seeking model.

We consider a contest between two groups g_i, $(i = 1, 2)$ where both group contest for a prize of value v_i. And each group consists of $N_j (j = 1, 2, ..., n)$ risk-neutral individuals.

Irrespective of the individual effort level, for each member of the winning group ,valuation of the prize is v_i and for losing the contest, the prize valuation =0.

Our model consists of two stages: at **stage** 1, group decides whether to communicate or not and at **stage** 2, players exert efforts simultaneously.

The probability of winning is given by:

$$p_i(e_i, e_j) = \begin{cases} \frac{X_g}{X_g + X_{-g}} & \text{if } X_g = X_{-g} \neq 0; \\ 0 & \text{otherwise.} \end{cases} \tag{2.1}$$

The utility of a player i of group g is given by the following equation:

$$u_{i_g} = (\frac{x_g}{x_g + x_{-g}}).v_g - c_g x_{ig} \tag{2.2}$$

Through out our analysis, we assume that all players within a specific group are identical with respect to all parameters such as valuation of prize, cost , preferences but they may be heterogeneous with respect to the other group either in one of the parameters i.e. two group members may be heterogeneous with respect to cost or the value of the prize[4].

2.1 Complete information:

In this section, our analysis is restricted to the complete information case when each and every player of both group have the perfect knowledge of all parameters with respect to the contest not only for own group members but also for the rival group members. In this complete information scenario, the expected payoff of i of group g is given by:

$$\pi_{i_g} = P_g.v_g - c_g.x_{ig} = (\frac{x_g}{x_g + x_{-g}}).v_g - c_g.x_{ig} \tag{2.3}$$

Maximizing eq (2.3) with respect to player i's effort level x_{ig} we get:

$$\frac{x_{-g}}{(x_g + x_{-g})^2}.v_g - c_g = 0 \tag{2.4}$$

Considering symmetric case for rival group, we get a similar equation:

$$\frac{x_g}{(x_g + x_{-g})^2}.v_{-g} - c_{-g} = 0 \tag{2.5}$$

Solving eq (2.4) & eq (2.5) for equilibrium level of effort, we get:

[4]Here in our analysis, for simplicity we only restrict our analysis to one source of heterogeneity.

$$x_g{}^* = \frac{c_{-g} v_{-g} v_g^2}{\left(c_g v_{-g} + c_{-g} v_g\right)^2}$$

$$x_{-g}{}^* = \frac{c_g v_{-g}^2 v_g}{\left(c_g v_{-g} + c_{-g} v_g\right)^2}$$

2.2 Incomplete information:

For comparing equilibrium effort level in case of homogeneous and heterogeneous groups , we define group specific characteristics - "advantage" (A) and "disadvantage"(D) group in the following way: When there exist cost heterogeneity, if the per unit level effort cost a group is lower than the rival group then the group is denoted as "advantage" group (A) and the rival group is denoted as "disadvantage" group (D). Thus, in case of cost heterogeneity, $c_A < c_D$. Similarly. When there exist prize value heterogeneity, if the prize value of a group is lower than the rival group then the group is denoted as "disadvantage" group (D) and the rival group is denoted as "advantage" group (A). Thus, in case of prize value heterogeneity, $v_A > v_D$.

When both groups are of the same type i.e. both groups are advantage group or both are disadvantage group, then we denote this type of contest as "even contest" and when one group is advantage group and other group is disadvantage group, then n we denote this type of contest as "uneven contest".

When there is incomplete information between groups, then one group does not know all the parameters of the other group with certainty but it knows that opponent group is advantage group with probability q and disadvantage group with probability $(1-q)$ where $0 < q < 1$. This probability distribution is common knowledge.

In this setting, player i of group g maximise his/her utility which is given by:

$$\pi_{i_g} = [r.\frac{x_g}{(x_g + x_A)} + (1-r)\frac{x_g}{(x_g + x_D)}]v_g - c_g.x_{i_g} \tag{2.6}$$

maximizing eq (2.6) with respect to player i's effort level x_{i_g} we get the FOC:

$$[r.\frac{x_A}{(x_g + x_A)^2} + (1-r)\frac{x_D}{(x_g + x_D)^2}]v_g - c_g = 0 \tag{2.7}$$

When $g = A$, eq (2.7) becomes:

$$[r.\frac{x_A}{(x_A + x_A)^2} + (1-r)\frac{x_D}{(x_A + x_D)^2}]v_A - c_A = 0 \tag{2.8}$$

When $g = D$, eq (2.7) becomes:

$$[r.\frac{x_A}{(x_D + x_A)^2} + (1-r)\frac{x_D}{(x_D + x_D)^2}]v_D - c_D = 0 \tag{2.9}$$

Solving eq (2.8) & eq (2.9), we can find out the equilibrium effort levels.

But this system of equations do not have any closed form solution. So, for simplification we assume $r = \frac{1}{2}$.

In case of cost heterogeneity and putting $r = \frac{1}{2}$, eq (2.8) & eq (2.9) become:

$$[\frac{1}{4x_A} + \frac{x_D}{(x_A + x_D)^2}]v = 2c_A \tag{2.10}$$

$$[\frac{1}{4x_D} + \frac{x_D}{(x_A + x_D)^2}]v = 2c_D \tag{2.11}$$

Solving eq (2.10) & eq (2.11), we get the following equilibrium effort levels:

$${x_{A_c}}^{**} = \frac{1}{8}v\left[\frac{4c_A}{(c_A + c_D)^2} + \frac{1}{c_D}\right] \tag{2.12}$$

$${x_{D_c}}^{**} = \frac{1}{8}v\left[\frac{4c_D}{(c_A + c_D)^2} + \frac{1}{c_A}\right] \tag{2.13}$$

In case of prize value heterogeneity and putting $r = \frac{1}{2}$, eq (2.8) & eq (2.9) become:

$$[\frac{1}{4x_A} + \frac{x_D}{(x_A + x_D)^2}]v_A = 2c \tag{2.14}$$

$$[\frac{1}{4x_D} + \frac{x_D}{(x_A + x_D)^2}]v_D = 2c \tag{2.15}$$

Solving eq (2.14) & eq (2.15), we get the following equilibrium effort levels:

$${x_{A_v}}^{**} = \frac{v_D}{8c}\left[\frac{4v_A}{(v_A + v_D)^2} + \frac{1}{v_D}\right] \tag{2.16}$$

$${x_{D_v}}^{**} = \frac{v_A}{8c}\left[\frac{4v_D}{(v_A + v_D)^2} + \frac{1}{v_A}\right] \tag{2.17}$$

3 Summary of equilibrium group effort level:

The following table summarizes the equilibrium effort level for both complete and incomplete information considering cost heterogeneity and prize value heterogeneity.

Information type	**Source of heterogeneity**	**Type of contests**	**Equilibrium group effort level**
Complete	cost of effort	Uneven	$[X_A, X_D]=[\frac{c_D v}{(c_A+c_D)^2}, \frac{c_A v}{(c_A+c_D)^2}]$
		Even	$[X_A{}^*, X_A{}^*]=[\frac{v}{4c_A}, \frac{v}{4c_A}]$
			$[X_D{}^*, X_D{}^*]=[\frac{v}{4c_D}, \frac{v}{4c_D}]$
	prize value	Uneven	$[X_A{}^*, X_D{}^*]=[\frac{{v_A}^2.v_D}{c(v_A+v_D)^2}, \frac{{v_D}^2.v_A}{c(v_A+v_D)^2}]$
		Even	$[X_A{}^*, X_A{}^*]=[\frac{v_A}{4c}, \frac{v_A}{4c}]$
			$[X_D{}^*, X_D{}^*]=[\frac{v_D}{4c}, \frac{v_D}{4c}]$
Incomplete	cost of effort	Uneven	$(X_D{}^{**}, x_D{}^{**})=[\frac{1}{8}v\left[\frac{4c_A}{(c_A+c_D)^2} + \frac{1}{c_D}\right], \frac{1}{8}v\left[\frac{4c_D}{(c_A+c_D)^2} + \frac{1}{c_A}\right]]$
	prize value	Uneven	$[X_A{}^{**}, x_D{}^{**}]=[\frac{v_D}{8c}\left[\frac{4v_A}{(v_A+v_D)^2} + \frac{1}{v_D}\right], \frac{v_A}{8c}\left[\frac{4v_D}{(v_A+v_D)^2} + \frac{1}{v_A}\right]]$

Lemma 3.1. *: The equilibrium group effort for uneven contests for cost heterogeneity is higher in complete information than incomplete information.*

Proof. see Appendix A □

Lemma 3.2. *The equilibrium group effort for uneven contests for value heterogeneity is higher in incomplete information than complete information.*

Proof. see Appendix B □

4 Rent dissipation:

The rent dissipation is defined as the ration of each group's equilibrium effort level to the valuation of the group.

Proposition 4.1. *1: In case of cost heterogeneity, the rent dissipation is higher for advantage group in case of complete information compared to the incomplete information contests.*

Proof. see Appendix C.A □

Proposition 4.2. *2: In case of cost heterogeneity, the rent dissipation is higher for disadvantage group in case of incomplete information compared to the complete information contests.*

Proof. see Appendix C.B □

Proposition 4.3. *3: In case of value heterogeneity, the rent dissipation is higher for advantage group in case of incomplete information compared to the complete information contests if the following holds:*

$$\frac{1}{2v_A} + \frac{1}{8v_D}(1 + \frac{v_D}{v_A})^2 > 1$$

Proof. see Appendix C.C □

Proposition 4.4. *4: In case of value heterogeneity, the rent dissipation is higher for disadvantage group in case of incomplete information compared to the complete information contests if the following holds:*

$$\frac{1}{2v_D} + \frac{1}{8v_A}(1 + \frac{v_A}{v_D})^2 > 1$$

Proof. see Appendix C.D □

5 Experimental set up:

We experimentally investigate heterogeneous group contests using our proposed model and its theoretical predictions. 6 players participate in contests where they are divided into two groups of equal size. Each player must belong to one of the groups and all players experts efforts simultaneously. Exerting effort is costly. Two groups are heterogeneous either with respect to unit effort cost or valuation of the prize. Since our aim is to study the impact of cheap talk communication in group contests, our experimental design employs four treatments as shown in table 1

All players are risk-neutral and all groups are identical except their unit effort cost or valuation of the prize. Efforts exerted by players in a sub-group are perfect substitute. Total effort for a group is the summation of efforts exerted by all players within the group. Two groups compete in contest over a public good prize. Under cost- heterogeneity, the valuation of the prize for both groups are equal and under value-heterogeneity, the valuation of prize differs across groups.

The utility of a player for a group is given by:

$$u_i = \frac{\textit{valuation of prize}}{3}.(\textit{Endowment - effort*unit effort cost})$$

In case of loosing group, the valuation of prize becomes = 0.

The benchmark for comparing experiment result is our theoretical predictions. Given the previous experimental results in literature, we can expect deviations from equilibrium predictions[5].

In every experimental session, participants were randomly placed into groups and each group consists of 6 participants. Each group is then converted into two equal subgroups. Players are randomly matched into groups prior to the experiment. And the groups remain fixed throughout the whole experiment. They play one round of practice session and 30 more rounds during the session.

Table 1: Experimental design and treatment level (126 total subjects)

Communication between groups	**Private communication within three-person groups**			
	Complete information		**Incomplete information**	
	Cost Heterogeneity	**Value Heterogeneity**	**Cost Heterogeneity**	**Value Heterogeneity**
No	com_cost_wo_chat (15 sessions, 30 subjects)	com_value_wo_chat (15 sessions, 30 subjects)	incom_cost_wo_chat (15 sessions, 30 subjects)	incom_value_wo_chat (15 sessions, 30 subjects)
Yes	com_cost_with_chat (15 sessions, 36 subjects)	com_value_with_chat (15 sessions, 36 subjects)	incom_cost_with_chat (15 sessions, 30 subjects)	incom_value_with_chat (15 sessions, 30 subjects)

The main issue that we investigate in this work is the comparison between pre-play cheap talk communication and no communication in group contests and its effect on group level effort provision as well as individual level effort. For this we are considering two environment :

(i). complete information group contest with cost and value heterogeneity

(ii). incomplete information group contest with cost and value heterogeneity

Moving from first environment to second environment brings more complexity with uncertainty as this brings kind of randomization with respect to opting strategy for the groups. To experimentally investigate, we consider the following hypothesis:

1. ***Hypothesis 1:*** Irrespective of the source of heterogeneity, the group effort(contribution) under complete information contest is higher in without cheap talk communication treatment.

2. ***Hypothesis 2:*** Irrespective of the source of heterogeneity, the group effort(contribution) under incomplete information contest is higher in without cheap talk communication treatment.

[5]Most laboratory studies report significant greater effort than the Nash predictions in case of group contests. [80]

3. ***Hypothesis 3:*** Group effort(contribution) does not vary according to the information criteria under cheap talk communication treatment.

4. ***Hypothesis 4:*** Cheap talk communication has no impact on group effort(contribution) both for the advantage and disadvantage groups.

The following table (2) summarizes the parameters used in our experiment.

Table 2: Experimental parameters

Experimental parameters				
Source of heterogeneity	**Group type**	**Cost**	**Vlaue**	**Group size**
effort cost	Advantage	$c_A = \frac{1}{3}$	$v_A = 50$	$n = 3$
	Disadvantage	$c_D = 1$	$v_D = 50$	
valuation of prize	Advantage	$c_A = 1$	$v_A = 150$	$n = 3$
	Disadvantage	$c_D = 1$	$v_D = 50$	

5.1 Experimental Process:

We conducted a series of 6 sessions between April, 07 to April, 25 (Year 2022) and collected data from 126 participants using O-tree[28]. We basically played four games namely incomplete information group contest without communication (30 participants), incomplete information group contest with communication (30 participants), complete information group contest without communication (30 participants), complete information group contest with communication (36 participants).Session wise summary are given in table 11. In our group treatments, each group consists of $N = 3$ subjects and all subjects in each winning groups receives the valuation of the prize as per equal sharing rule. The stage game has been played for 30 rounds; first they play one practice round[6], followed by 15 rounds with cost heterogeneity and then 15 rounds with value heterogeneity. At the beginning of the experiment, subjects were grouped randomly into teams of 6 players and then each team was divided into groups of 3 subjects and they remained in the same group through out the experimental session for 30 periods. They were given instructions for the whole experiment and then they had to answer few questions[7] to test their understanding of the experimental process. At the beginning of each period, each subjects were given 20 experimental tokens out of which they choose their contribution level. Any subject can contribute any integer number between 0 and 20. In case of complete information contests, both the competing groups knew all the parameters and for incomplete information contests, some information were not revealed[8] No participants dropped out during the whole experiments.

The base line treatment consists of a group contest without any communication. This is applicable both for complete information and incomplete information. In treatment with cheap talk communication, each subject, before making their choice of contribution, could chat anonymously with his/her own group members via a chat window. For all chat messages, we asked subjects to follow some basic

[6]There is no payoff from this round, this is just to make sure that subjects get to used to the environment of the experiment.

[7]A subject could not proceed further if they failed to give all correct answers.

[8]for example, in case of cost heterogeneity, groups did not know each other's unit effort cost or in case of value heterogeneity, groups did not know each other's valuation of the prize. All they had a common prior about these parameters.

rules such as not to reveal their identity, not to use foul languages. All communications were recorded.

For the cheap talk communication treatment, after the chat period, all the subjects simultaneously chose their contribution decision, and then computer decided the winning group that made highest total contribution. At the end of each round, subjects were informed about the result of the contest. At the end of this session, computer picked a random period for the payment for each subject. At the very end of this experimental session, subjects were given online survey questions to fill up.

All earnings were converted into INR at the rate of 10 experimental currency to 1 INR. In addition, a participation fee of INR 50 was paid as a participation fees to each subject.Payments were done mostly in cash but for some participants took payments through UPI transfer mode. Sessions lasted about 60-80 minutes on average.

6 Experimental Results:

6.1 Aggregate group results:

Table 3 presents both the experimental aggregate group effort for with and without communication treatments as well as the theoretical equilibrium predictions(without nay communication). This result is categorized both for the advantage and disadvantage groups as well as for complete and incomplete information. From this table information, we can estimate the deviation of the experimental results from out theoretical predictions.

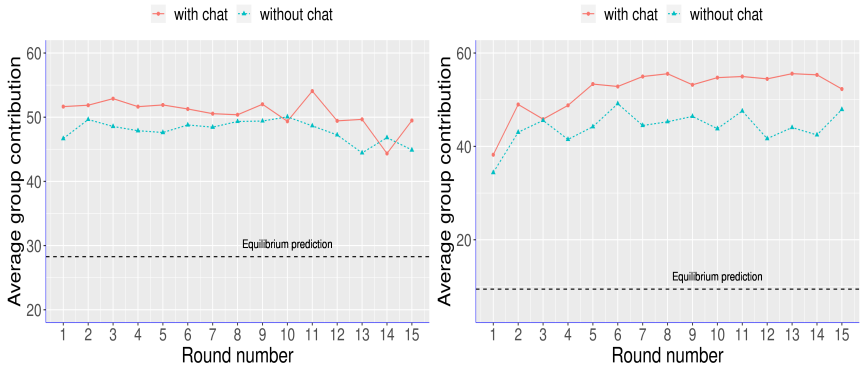
Table 3: Within group comparison

TREATMENT	GROUP TYPE	CONTEST INFORMATION	COST HETEROGENEITY		VALUE HETEROGENEITY		WILCOX P-VALUE
			OBSERVED PREDICTION	THEORETICAL PREDICTION	OBSERVED PREDICTION	THEORETICAL PREDICTION	
WITH CHEAP TALK	ADVANTAGE	COMPLETE INFORMATION	50.7 (14.00)		52.4 (13.60)		0.008258748
WITHOUT CHEAP TALK	ADVANTAGE	COMPLETE INFORMATION	47.9 (9.56)	28.125	51 (8.20)	28.125	0.000148749
WITH CHEAP TALK	DISADVANTAGE	COMPLETE INFORMATION	51.9 (10.70)		54.4 (9.19		0.001154686
WITHOUT CHEAP TALK	DISADVANTAGE	COMPLETE INFORMATION	44.1 (12.40)	9.375	49.1 (9.36)	9.375	0.00001543415
WITH CHEAP TALK	ADVANTAGE	INCOMPLETE INFORMATION	44.1 (12.30)		44.6 (14.40)		0.6214589
WITHOUT CHEAP TALK	ADVANTAGE	INCOMPLETE INFORMATION	51 (7.35)	10.94	51.8 (7.92)	0.219	0.1310503
WITH CHEAP TALK	DISADVANTAGE	INCOMPLETE INFORMATION	48.7 (8.92)		50.8 (9.11)		0.05750869
WITHOUT CHEAP TALK	DISADVANTAGE	INCOMPLETE INFORMATION	52 (7.05)	32.81	52.9 (7.86)	0.219	0.1502943

Note: values in parenthesis are standard deviations

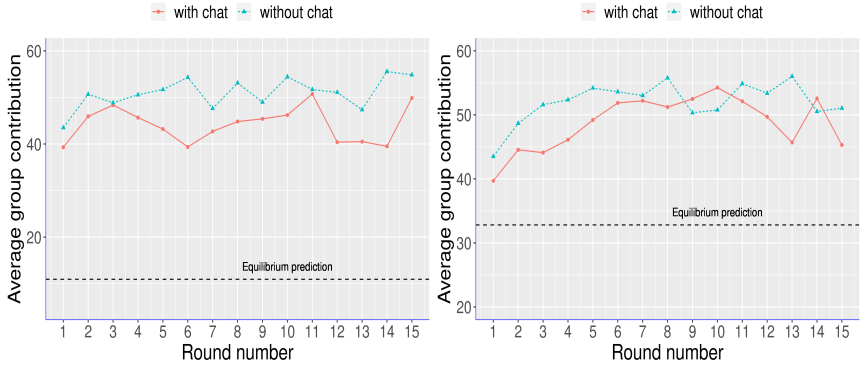
Now we focus on the group level contribution both in the complete information and incomplete information contests. Our prime interests lies in understanding the aggregate group level efforts due to the effect of cheap talk. The average level of aggregate group level efforts for cost heterogeneity are shown in Figure 1 and Figure 2 . Panel (A) depicts for advantage group and panel (B) depicts for disadvantage groups for all 15 periods. In Figure 1, we observe downward trend for advantage groups and upward trend for disadvantage groups. Under cost heterogeneity and with complete information, the average group contribution for the advantage group with cheap talk and without cheap talk are 50.7 and 47.9 respectively. For the disadvantage groups, the average group contribution for the advantage group with cheap talk and without cheap talk are 51.9 and 44.1 respectively. This aggregate contribution shows over-bidding in contests. With cost heterogeneity and complete information, we

find higher aggregate group contribution in the presence of cheap talk (p-value = 0.00000426, Wilcox p-stat) for advantage group (panel A, fig 1). And similar observation is found for disadvantage group as well (panel B, fig 1).



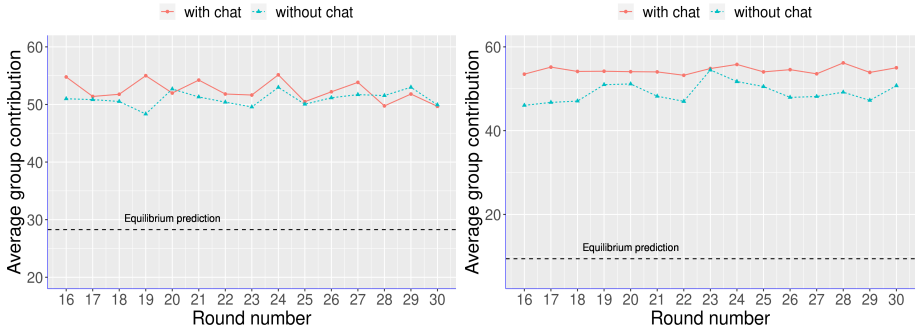
(a) For Advantage group (b) For Disadvantage group

Figure 1: Aggregate group effort in complete information group contest with cost heterogeneity



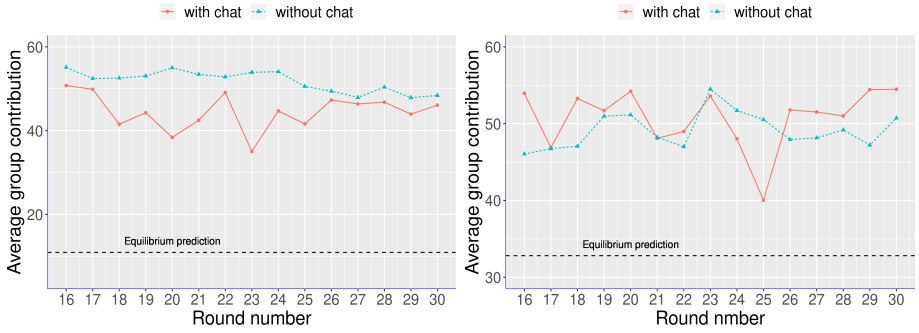
(a) For Advantage group (b) For Disadvantage group

Figure 2: Aggregate group effort in incomplete information group contest with cost heterogeneity



(a) For Advantage group (b) For Disadvantage group

Figure 3: Aggregate group effort in complete information group contest with value heterogeneity



(a) For Advantage group (b) For Disadvantage group

Figure 4: Aggregate group effort in incomplete information group contest with value heterogeneity

Under cost heterogeneity, in the incomplete information treatment, the average group contribution for the advantage group with cheap talk and without cheap talk are 44.1 and 51 respectively (panel A, fig 2) and for the disadvantage groups, the average group contribution for the advantage group with cheap talk and without cheap talk are 48.7 and 52 respectively (panel B, fig 2). From the statistical analysis, we observe that for advantage group aggregate contribution is significantly lower for cheap talk than without cheap talk (p-value = 0.0002562, Wilcox p-stat) and similar results holds for disadvantage groups under same treatment (p-value = 0.01246, Wilcox p-stat).

We clearly observe over-bidding phenomenon with respect to the theoretical prediction both under complete and incomplete information[9]. In reference to the existing literature, our findings of

[9]p-value $< 2.2e-16$

over-bidding find no inconsistency with the results of [74].

Result 1:

There is significantly overbidding of aggregate contribution for advantage and disadvantage groups in group contest with cost heterogeneity both under complete and incomplete information.

Result 2:

The aggregate contribution (effort) is significantly lower in group contests with cheap talk than contests without cheap talk under incomplete information and the aggregate contribution (effort) is significantly higher in group contests with cheap talk than without cheap talk contests for complete information under cost heterogeneity.

The average level of aggregate group level efforts for value heterogeneity are shown in Figure 3 and Figure 4. Panel (A) depicts for advantage group and panel (B) depicts for disadvantage groups for rounds 16 to 30. Under value heterogeneity and with complete information, the average group contribution for the advantage group with cheap talk and without cheap talk are 52.4 and 51 respectively. For the disadvantage groups, the average group contribution for the advantage group with cheap talk and without cheap talk are 54.4 and 49.1 respectively. This aggregate contribution shows over-bidding in contests. With complete information, we find higher aggregate group contribution in the presence of cheap talk (p-value = 0.000000124, Wilcox p-stat) for advantage group (panel A, fig 1). And similar observation is found for disadvantage group as well (panel B, fig 1) with p-value = 0.00000000183.

Under value heterogeneity, in the incomplete information treatment, the average group contribution for the advantage group with cheap talk and without cheap talk are 44.6 and 51.8 respectively (panel A, fig 3) and for the disadvantage groups, the average group contribution for the advantage group with cheap talk and without cheap talk are 50.8 and 52.9 respectively (panel B, fig 4). From the statistical table, we observe that for advantage group aggregate contribution is significantly lower for cheap talk than without cheap talk (p-value = 0.0004202, Wilcox p-stat) and similar results holds for disadvantage groups under same treatment (p-value = 0.005158, Wilcox p-stat).

Result 3:

There is significantly overbidding of aggregate contribution for advantage and disadvantage groups in group contest with value heterogeneity both under complete and incomplete information.

Result 4:

The aggregate contribution (effort) is significantly lower in group contests with cheap talk than contests without cheap talk under incomplete information and the aggregate contribution (effort) is

significantly higher in group contests with cheap talk than without cheap talk contests for incomplete information under value heterogeneity.

Result 5:

When there is incomplete information in contests, allowing cost-less pre-play communication (cheap talk) reduces overbidding significantly.

6.2 Group level Rent dissipation:

Figure 5 and 6 shows the levels of rent dissipation[10] under cost heterogeneity and Figure 7 and 8 plot the same for value heterogeneity.

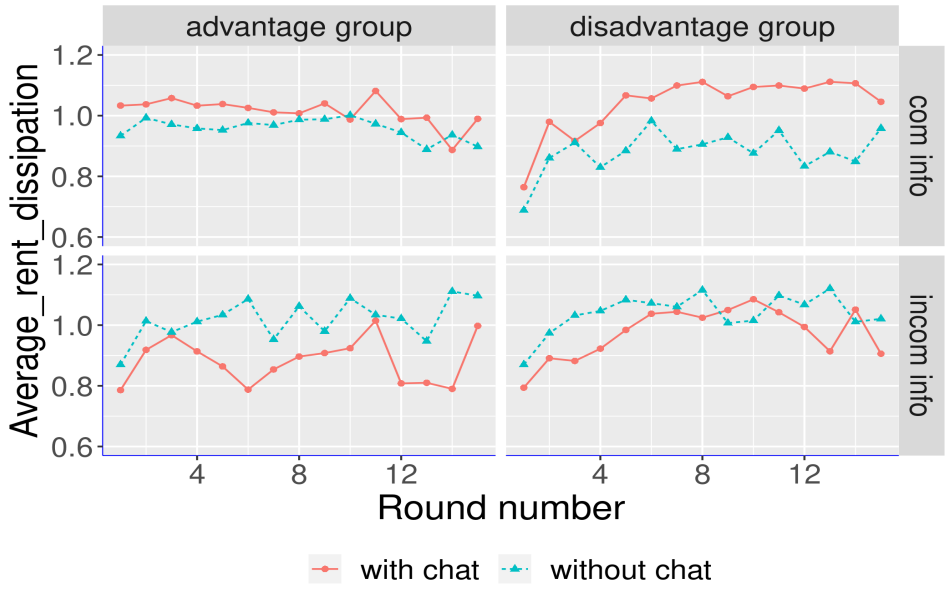


Figure 5: Rent dissipation across different communication rules under cost heterogeneity

An apparent look at Figure 5 indicates that both for advantage as well as disadvantage groups, the rent dissipation are relatively higher under cheap talk treatment in case of complete information group contests under cost heterogeneity. But for incomplete information group contests, the trend seems to be the opposite. Using the table 5, we statistically compare the differences. From figure 5, we find that in case of complete information, the average rent dissipation for advantage groups in cheap talk treatment is more than 100 % for first 12 rounds (out of 15 rounds) and in no cheap talk treatment, this value lies between 90 to 100 %. Interestingly, the opposite case happens in case of incomplete information. From the table 5, we find that for advantage groups, the mean rent

[10]Rent dissipation is defined as the ratio of group total effort to the valuation of the prize for the group

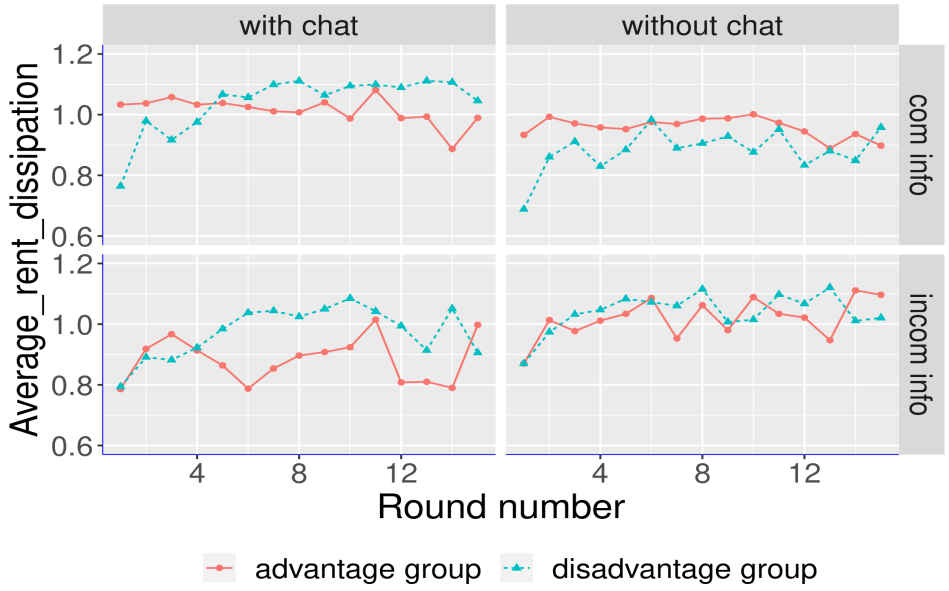


Figure 6: Rent dissipation across different advantage groups under cost heterogeneity

dissipation is significantly higher (the p-value is 2.62e-05) in case of complete information (mean rent dissipation is about 77 %) in compare to incomplete information (mean rent dissipation is about 66 %). But for no cheap talk treatment, we do not find any significant differences in the mean values for the advantage group. For the disadvantage groups, from figure 6, it is evident that under complete information, though rent dissipation tends to increase as the rounds progress but it is comparatively higher for the cheap talk treatment and for most of the rounds, rent dissipation is more than 100 %. Almost similar trend is followed in case of incomplete information. From the table 5, we find that for disadvantage groups, the mean rent dissipation is significantly higher (the p-value is 0.000645) in case of complete information (mean rent dissipation is about 106 %) in compare to incomplete information (mean rent dissipation is about 99 %). But for no cheap talk treatment, we find that for disadvantage groups, the mean rent dissipation is significantly lower (the p-value is 1.42e-07) in case of complete information (mean rent dissipation is about 93 %) in compare to incomplete information (mean rent dissipation is about 104 %).

Result 6a:

In group contests with cost heterogeneity only, under cheap talk treatment, the mean rent dissipation in complete information is higher than that of incomplete information both for advantage and disadvantage groups.

Result 6b:

In group contests with cost heterogeneity only, under no cheap talk treatment, there is no significant difference in mean rent dissipation for the advantage groups irrespective of the information condition but for disadvantage group, the mean rent dissipation in complete information is lower than that of incomplete information.

Table 4: Mean Rent Dissipation comparison within groups

HETEROGENEITY TYPE	INFORMATION TYPE	GROUP TYPE	MEAN GROUP RENT DISSIPATION		WILCOX P-VALUE		
			WITH CHAT	WITHOUT CHAT	EQUAL	LESS	GRATER
COST HETEROGENEITY	COMPLETE INFORMATION	ADVANTAGE GROUP	1.01 (0.281)	0.958 (0.191)	8.53E-06	0.9999958	4.26E-06
		DISADVANTAGE GROUP	1.04 (0.213)	0.882 (0.247)	1.22E-07	0.9999999	6.11E-08
	INCOMPLETE INFORMATION	ADVANTAGE GROUP	0.883 (0.246)	1.02 (0.147)	0.0005123058	0.0002561529	0.9997474
		DISADVANTAGE GROUP	0.975 (0.178)	1.04 (0.141)	0.02491505	0.01245753	0.9876633
VALUE HETEROGENEITY	COMPLETE INFORMATION	ADVANTAGE GROUP	0.524 (0.136)	0.510 (0.0820)	2.48E-07	0.9999999	1.24E-07
		DISADVANTAGE GROUP	1.09 (0.184)	0.983 (0.188)	3.65E-09	1	0.9876633
	INCOMPLETE INFORMATION	ADVANTAGE GROUP	0.446 (0.144)	0.518 (0.0792)	0.0008404725	0.0004202362	0.9995854
		DISADVANTAGE GROUP	1.02 (0.182)	1.06 (0.157)	0.01031592	0.00515796	0.9948977
Note: Standard errors are given in parenthesis.							

Table 5: Mean Rent Dissipation comparison between groups

GROUP TYPE	COMMUNICATION TYPE	MEAN GROUP RENT DISSIPATION		WILCOX T TEST			T-TEST		
		COM INFO	INCOM INFO	EQUAL	LESS	GREATER	EQUAL	LESS	GREATER
ADVANTAGE GROUP	WITH CHAT	0.7688770 (0.330)	0.6640573 (0.298)	4.47E-05	1	2.23E-05	2.62E-03	0.9986885	1.31E-03
	WITHOUT CHAT	0.7339740 (0.268)	0.7685243 (0.278)	0.3351	0.1676	0.8328	0.2739568	0.1369784	0.8630216
DISADVANTAGE GROUP	WITH CHAT	1.0634890 (0.200)	0.9953667 (0.181)	1.82E-10	1	9.08E-11	0.001291541	0.9993542	0.0006457703
	WITHOUT CHAT	0.9323807 (0.225)	1.0484253 (0.149)	1.20E-06	5.98E-07	1	2.84E-07	1.42E-07	0.9999999
Note: Standard errors are given in parenthesis.									

Now, looking at Figure 7, we do not find any clear trend except the top right corner, where average rent dissipation for no cheap talk treatment under complete information is relatively higher for the advantage group. Except that top right corner, there is evidences for more than 100 % rent dissipation. If we focus on the cheap talk treatment effect, under complete information, in case of advantage group, the mean value of rent dissipation under cheap talk treatment is about 52 % and that for the without cheap talk treatment is about 51 %; under incomplete information, in case of advantage group, the mean value of rent dissipation under cheap talk treatment is about 44 % and that for the without cheap talk treatment is about 51 %. Using statistical analysis as provided in table 4, it is evident that under complete information rent dissipation for the advantage group is significantly higher for cheap talk treatment (p-value is 1.24e-07) but under incomplete information it is lower for the cheap talk treatment (p-value is 0.00042). Figure 8 depicts rent dissipation for both advantage and disadvantage groups under different treatment and information regime. We here find a clear trend – for all cases in figure 8, average rent dissipation for advantage group is lower than that for disadvantage group and this is statistically significant. The same can be confirmed from the statistical analysis as shown in table 5.

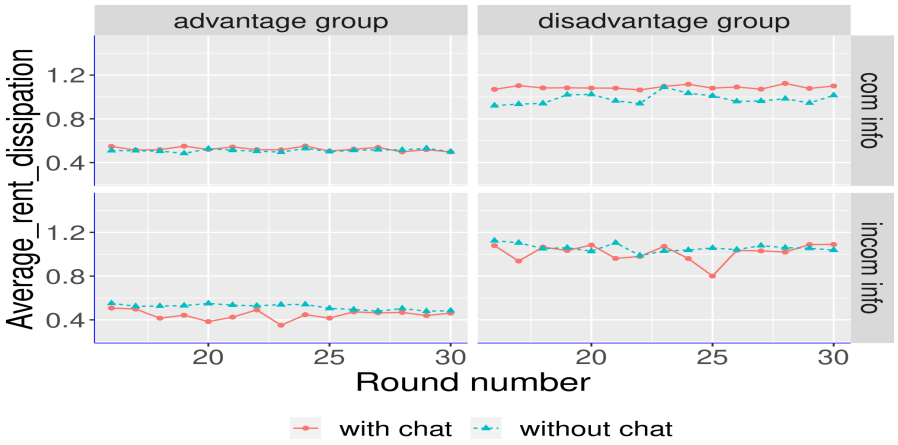


Figure 7: Rent dissipation across different communication rules under value heterogeneity

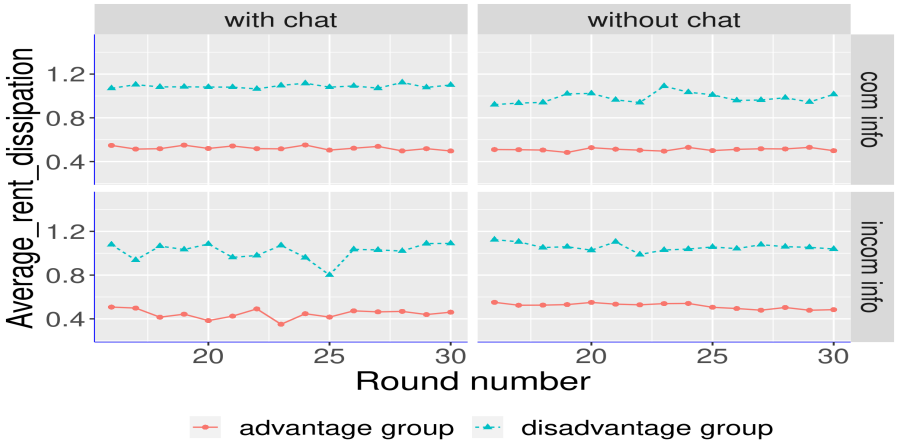


Figure 8: Rent dissipation across different advantage groups under value heterogeneity

Result 6c:

In group contests with value heterogeneity only, rent dissipation for the advantage group is significantly higher in cheap talk treatment than without cheap talk treatment under complete information but the opposite holds true under incomplete information.

Result 6d:

In group contests with value heterogeneity only, rent dissipation for the disadvantage group is significantly higher in compare to advantage group irrespective of the information and treatment protocol.

6.3 Within group coordination under communication:

Figure 9 & 10 show the average group effective (minimum) contribution for complete information and incomplete information respectively. In without cheap talk communication treatment, the average group effort should be between 0 and 12.5 under cost heterogeneity and that ,under value heterogeneity, should be between 0 and 37.5 for the advantage groups and 0 and 12.5 for the disadvantage groups. As shown in table 13, the actual average contribution (effort) under cost heterogeneity is 46 and 51.5 for complete and incomplete information respectively and that under value heterogeneity is 50.1 and 52.3 for complete and incomplete information respectively. This actually indicates that subjects do not learn to coordinate their contribution(effort) at a substantial level.

And with cheap talk treatment, the actual average contribution (effort) under cost heterogeneity is 51.3 and 46.4 for complete and incomplete information respectively and that under value heterogeneity is 53.4 and 47.7 for complete and incomplete information respectively. In compare to the without cheap talk treatment, average group effort in cheap talk treatment indicates some tendency that players learn to coordinate their efforts at group level. To measure the extent of such coordination, we analyse how much efforts(contributions) of a group is wasted due to the group member's choices. We define average waste effort of a group taking the average of differences between group's total effort and the theoretical equilibrium effort without any communication.

A group can achieve complete coordination when the average waste effort equals zero. In case of complete information, when no within group communication is allowed, for the advantage groups, the average waste effort under cost heterogeneity is 19.8 (22.6 for communication treatment) and for the disadvantage groups it is 34.7 (42.6 for communication treatment) and under value heterogeneity it is 22.9 for the advantage groups (22.4 for communication treatment) and 39.8 for the disadvantage groups (45 for communication treatment). Figure 11 indicates that under complete information, groups without cheap talk communication treatment substantially reduced their miscoordination in compare to with cheap talk treatment (Wilcoxon signed rank test, p-value < 0.05). [11]. This findings pertaining to the complete information scenario stands in contrast to the earlier findings for higher coordination due to within group communication([81], [9]). As table 6 indicates that, under complete information contests, the average waste effort(contribution) is much lower for the advantage group

[11] For, com_cost_ad contest $\rightarrow$ p-value = $8.527e^{-06}$;
com_cost_disad contest $\rightarrow$ p-value = $1.22e^{-07}$;
com_value_ad contest $\rightarrow$ p-value = $1.242e^{-07}$;
com_value_disad contest $\rightarrow$ p-value = $1.825e^{-09}$

than that of the disadvantage groups.

Table 6: Summary statistics of contribution(effort) by treatment for advantage and disadvantage groups

Treatment				Average individual effort	Average individual minimum effort	Average group effort	Average waste effort
Complete information	**Cost heterogeneity**	**Advantage group**	**Cheap talk**	16.9 (5.83)	14.6 (7.87)	50.7 (14.0)	22.6 (14.0)
			No cheap talk	16.0 (4.84)	12.4 (5.83)	47.9 (9.56)	19.8 (9.56)
		Disadvantage group	**Cheap talk**	17.3 (4.30)	15.3 (5.63)	51.9 (10.7)	42.6 (10.7)
			No cheap talk	14.7 (5.22)	11.4 (5.46)	44.1 (12.4)	34.7 (12.4)
	Value heterogeneity	**Advantage group**	**Cheap talk**	17.5 (5.31)	15.8 (7.17)	52.4 (13.6)	22.4 (13.6)
			No cheap talk	17.0 (4.44)	13.6 (5.82)	51 (8.2)	22.9 (8.20)
		Disadvantage group	**Cheap talk**	18.1 (4.12)	16.3 (5.73)	54.4 (9.19)	45.0 (9.19)
			No cheap talk	16.4 (4.31)	13.6 (5.25)	49.1 (9.36)	39.8 (9.38)
Incomplete information	**Cost heterogeneity**	**Advantage group**	**Cheap talk**	14.7 (5.91)	10.6 (6.64)	44.1 (12.3)	33.2 (12.3)
			No cheap talk	17.0 (3.88)	13.9 (4.27)	51 (7.35)	40.0 (7.35)
		Disadvantage group	**Cheap talk**	16.2 (4.16)	13.3 (4.62)	48.7 (8.92)	15.9 (8.92)
			No cheap talk	17.3 (3.64)	14.7 (4.42)	52 (7.05)	19.2 (7.05)
	Value heterogeneity	**Advantage group**	**Cheap talk**	14.9 (5.86)	11.9 (6.59)	44.6 (14.4)	44.3 (14.4)
			No cheap talk	17.3 (4.13)	14.1 (5.13)	51.8 (7.92)	51.6 (7.92)
		Disadvantage group	**Cheap talk**	16.9 (4.29)	14.0 (4.54)	50.8 (9.11)	50.6 (9.11)
			No cheap talk	17.6 (3.52)	15.4 (4.24)	52.9 (7.86)	52.6 (7.86)

Note: Standard errors are shown in parentheses

Result 7a:

In case of complete information contest, irrespective the source of heterogeneity, substantial coordination exists within groups even without cheap talk communication.

In case of incomplete information, when no within group communication is allowed, for the advantage groups, the average waste effort under cost heterogeneity is 40 (33.2 for communication treatment) and for the disadvantage groups it is 19.2 (15.9 for communication treatment) and under value heterogeneity it is 51.6 for the advantage groups (44.3 for communication treatment) and 52.6 for the disadvantage groups (50.6 for communication treatment). Figure 12 indicates that under incomplete information, groups with cheap talk communication treatment substantially reduced their miscoordination in compare to without cheap talk treatment (Wilcoxon signed rank test, p-value < 0.05).[12]. This findings pertaining to the incomplete information scenario stands in support to the

[12]For, $incom\_cost\_ad$ contest $\rightarrow$ p-value = 0.0002562 ;
$incom\_cost\_disad$ contest $\rightarrow$ p-value = 0.01246 ;
$incom\_value\_ad$ contest $\rightarrow$ p-value = 0.0004202 ;
$incom\_value\_disad$ contest $\rightarrow$ p-value = 0.005158

earlier findings for higher coordination due to within group communication([81], [9]).From table 6, it is evident that, for incomplete information contests the average waste effort(contribution) is much lower for the disadvantage group than that of the advantage groups.

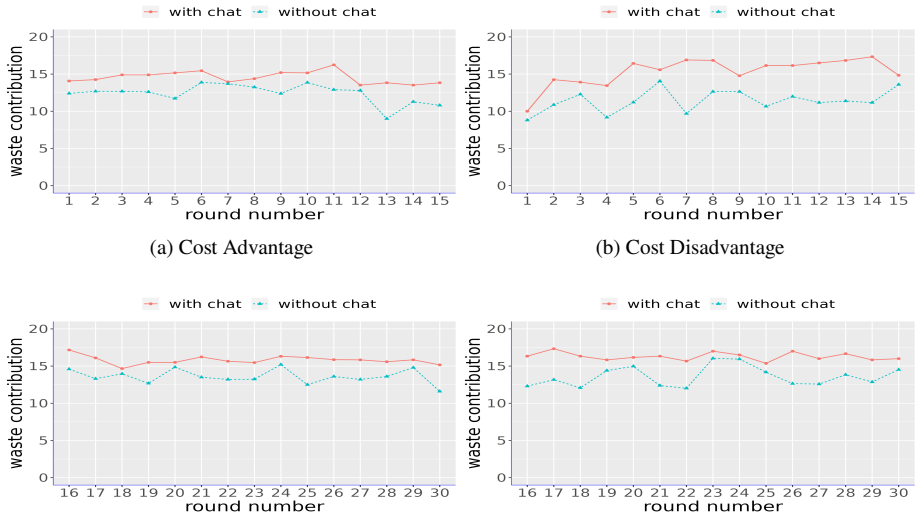
Result 7b:

Relative to without cheap talk communication, within group communication improves coordination under incomplete information. And this does not hold for the complete information contests.

Figures 9 and 10 display the average minimum individual effort within each group across the periods of the experiment both for complete information and incomplete information. Advantage and disadvantage groups are shown separately both for cost heterogeneity as well as value heterogeneity. For complete information, minimum group contribution is higher under communication treatment (Wilcoxon p-vale < 0.05) and in case of incomplete information, minimum group contribution is higher when no communication is allowed within groups (Wilcoxon p-vale < 0.05).

Result 7c:

Relative to without cheap talk communication, within group communication increases group minimum effort(contribution) for complete information contests and reduces group minimum effort(contribution) for incomplete information contests



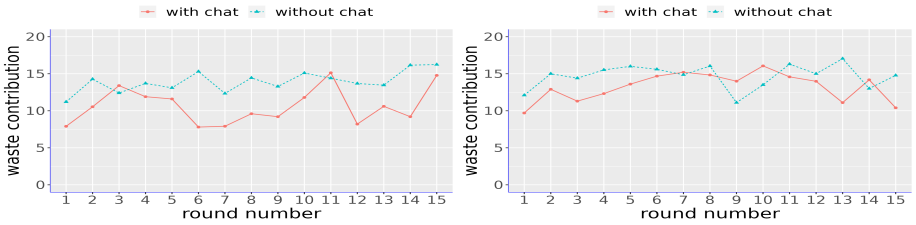
(a) Cost Advantage

(b) Cost Disadvantage

(c) Value Advantage

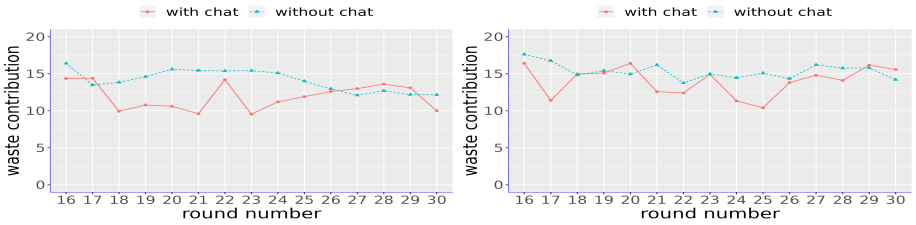
(d) Value Disadvantage

Figure 9: Average minimum group effort in complete information group contest



(a) Cost Advantage

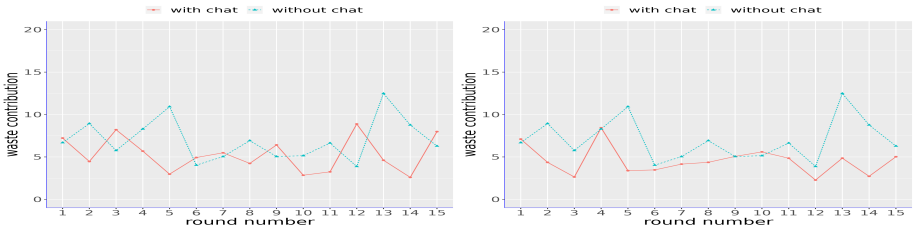
(b) Cost Disadvantage



(c) Value Advantage

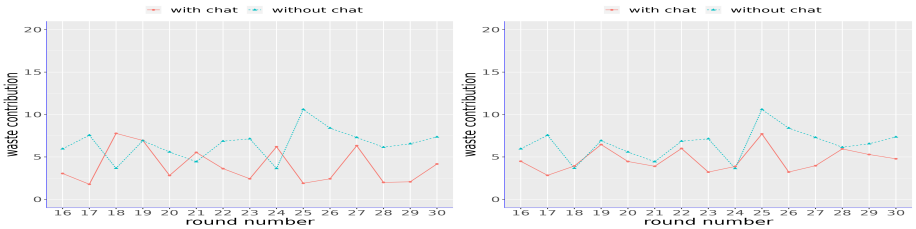
(d) Value Disadvantage

Figure 10: Average minimum group effort in incomplete information group contest



(a) Cost Advantage

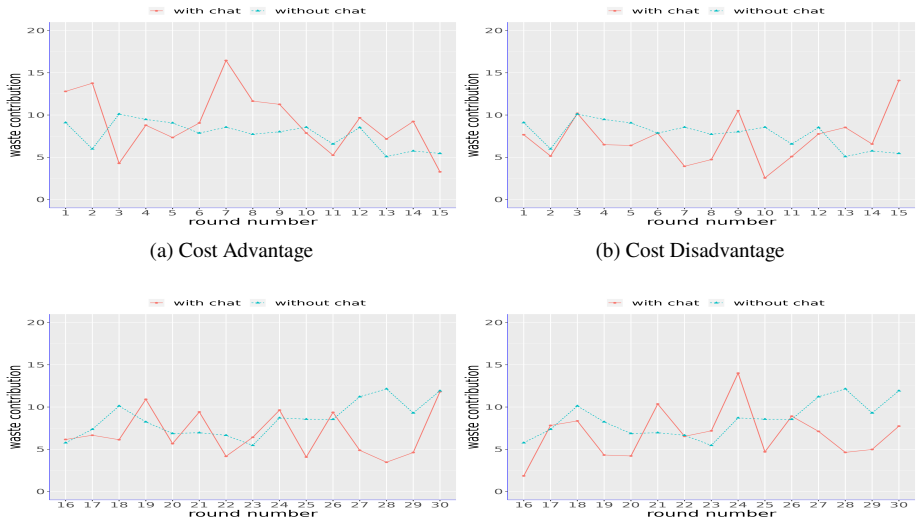
(b) Cost Disadvantage



(c) Value Advantage

(d) Value Disadvantage

Figure 11: Average waste effort in complete information group contest



(a) Cost Advantage

(b) Cost Disadvantage

(c) Value Advantage

(d) Value Disadvantage

Figure 12: Average waste effort in incomplete information group contest

6.4 Group level regression analysis:

6.4.1 Effect of communication:

Table 7 represents regression analysis that allows for tests of information both for advantage and disadvantage groups. It reports the result of random effect models of aggregate group effort choices on cheap talk, advantage group, cost and value heterogeneity. Further, when testing for information effects, it allows us to include all data points regardless of the type of heterogeneity in the contest. Here advantage_group, cheap_talk, cost and value all are dummy binary variables. For advantage groups, the variable 'advantage_group' takes value 1, for groups which engage in pre-play communications, the variable 'cheap_talk' takes value 1, when there is cost heterogeneity, the variable 'cost' takes value 1 and for value heterogeneity, the variable 'value' takes the value 1, else all these variables take value 0. We find, the coefficient on 'cheap_talk' dummy to be positive and significant for complete information contests and for incomplete information contests, it is negative and significant for the aggregate group contribution.

The estimate on cheap talk is positive and significant for complete information treatment but significantly negative for incomplete information treatment. In incomplete information contests, when averaged across heterogeneity of sources, cheap talk communication significantly increases group-level effort by 5.032 points and in complete information contests, when averaged across heterogeneity of sources, cheap talk communication significantly decreases group-level effort by 5.32 points. This significant impacts are largely driven by value and cost treatment. This means that when intra-group communication is allowed, aggregate group effort tends to get higher under complete information contests and it tends to get lower under incomplete information contests. In other way, when engaging in intra-group communication, groups behave aggressively under complete information but coordination gets better under incomplete information. Thus we fail to reject our hypothesis H2 and can

reject our hypothesis H4. But our finding is consistent with our **Result 7c**. One intuitive explanation could be that since there are uncertainties under incomplete information, if more the subjects tend send messages about cooperation or indicate in this direction, then more coordination can be seen within the groups.

We find similar estimate on advantage group except it is not significant for complete information. Controlling other factor including cheap talk, aggregate group effort gets significantly reduced under incomplete information fro the advantage group. That means more coordination within the group can be observed for the advantage groups. Our theoretical equilibrium also suggests the same. And we too have seen similar statistical results in table 6.

Table 7: Effect of communication

	Dependent variable: Group contribution					
	OLS		group cluster		round level cluster	
	com info	incom info	com info	incom info	com info	incom info
	(1)	(2)	(3)	(4)	(5)	(6)
cheap talk	4.321***	-4.8438***	4.321	-4.84	4.321***	-4.84***
	(0.876)	(0.7937)	(4.266)	(2.62)	(0.324)	(0.514)
advantage group	0.392	-3.2369***	0.392	-3.24	0.392	-3.24***
	(0.872)	(0.7937)	(4.341)	(2.62)	(0.609)	(0.572)
cost	-2.979***		-2.979***		-2.979***	
	(0.872)		(0.746)		(0.551)	
value		1.0523		1.05		1.05
		(0.7937)		(1.29)		(0.746)
constant	49.327***	52.9905***	49.327***	52.99***	49.327***	52.99***
	(0.894)	(0.7937)	(3.527)	(2.10)	(0.431)	(0.760)
Note: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; Clustered standard errors are given in parenthesis						
Regression (1) & (2) are OLS without clustering						
Regression (3) & (4) are OLS with clustering at group level						
Regression (5) & (6) are OLS with clustering at round number						

6.4.2 Effect of information:

Regression table 8 allows us to examine the effect of information for advantage and disadvantage groups' total contribution. Specification (1) in table 8 shows the result for advantage group and specification (1) shows it for disadvantage groups. Controlling all other factors, we do not find any significant impact of cheap talk communication on group contributions. The average group contribution is significantly increased when source of heterogeneity is considered. It is positively and significantly impacted due to the value heterogeneity when we control all other factors (it increases average group-level effort by 2.316 points. That means value heterogeneity increases group effort where as cost heterogeneity decreases the average group contribution.

Table 8: Effect of information

	Dependent variable: group contribution	
	Group Type	
	Ad Group	Disad Group
	(1)	(2)
cheap_talk	−2.275	−2.275
	(4.081)	(4.081)
value	2.316**	2.316**
	(1.002)	(1.002)
incomplete	−1.990	−1.990
	(4.168)	(4.168)
value:incomplete	−1.685	−1.685
	(2.307)	(2.307)
Constant	50.670***	50.670***
	(3.529)	(3.529)

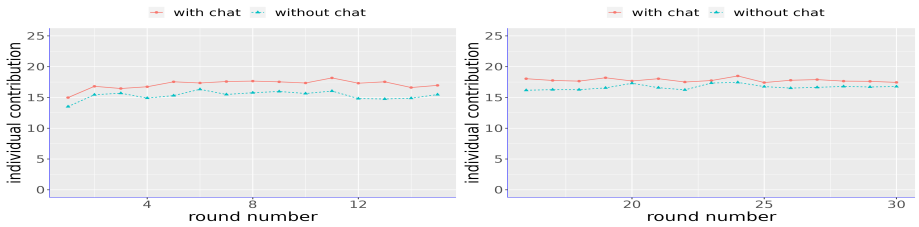
Note: *p<0.1; **p<0.05; ***p<0.01.
Values in parentheses indicate clustered standard errors.
'Ad group' and 'Disad group' indicate advantage and disadvantage groups respectively.

6.5 Individual contribution analysis:

After analysing aggregate group contributions(efforts), we now concentrate on noticeable variations in individual contribution. To study the distinctions between contests with and without cheap talk both in complete and incomplete information environment at the player level, we calculate average effort (contribution) exerted by individual players [Figure 13 and 14]. It is note worthy to mention that all the Nash equilibrium predictions are only applicable at the group level and any existing theory does not suggest any direction with respect to aggregation of group level Nash prediction from the individual contribution levels. We compare the variation in individual contributions within a team to a symmetric distribution of contributions[13]. To find out the degree of variation of individual contributions within a group, we measure simple variance. Higher value of coefficient[14] of variation (CV) would imply higher spread of individual contributions. Table 16 shows the average player contribution for both the treatment along with the group wise standard deviations and coefficient of variation. Fig 17, Fig 18, Fig 19, Fig 20 *show the dis-aggregated analysis of player contribution for advantage and disadvantage groups under complete as well as incomplete information.*

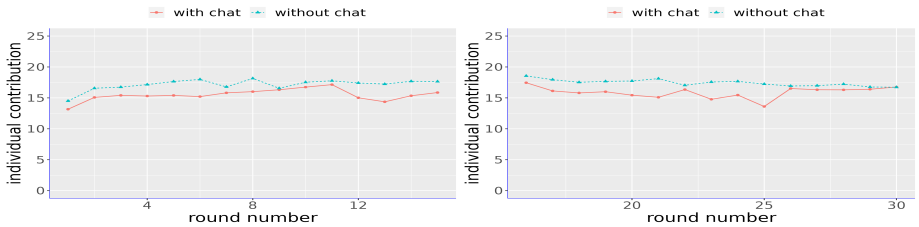
[13]It is fair to assume that – since team members are uniform, an equitable allocation of resources would entail that the whole team contribution is distributed equally among the three members.

[14]In our analysis, a measure of CV more than 35% is treated as significantly higher CV



(a) Cost Heterogeneity (b) Value Heterogeneity

Figure 13: Average player contribution in complete information group contest



(a) Cost Heterogeneity (b) Value Heterogeneity

Figure 14: Average player contribution in incomplete information group contest

First we consider the complete information group contest for the advantage groups.Under cost heterogeneity, average player contribution is significantly higher (wilcox p-value is $4.38e^{-16}$) in cheap talk treatment (it is about 16.9 tokens) than without cheap talk treatment (it is about 15.9 tokens) and average coefficient of variation (CV) for both the treatments are about 30%. And under value heterogeneity, average player contribution is significantly higher (wilcox p-value is $1.608e^{-10}$) in cheap talk treatment (it is about 17.4 tokens) than without cheap talk treatment (it is about 16.9 tokens) and average coefficient of variation (CV) for communication treatments is about 30% and for without communication treatment it is around 30%. For the disadvantage groups, under cost heterogeneity, average player contribution is significantly higher (wilcox p-value is $2.2e^{-16}$) in cheap talk treatment (it is about 17.3 tokens) than without cheap talk treatment (it is about 14.6 tokens) and average coefficient of variation (CV) for communication treatments is about 25% and for without communication treatment it is around 35%. For the value heterogeneity, average player contribution is significantly higher (wilcox p-value is $2.2e^{-16}$) in cheap talk treatment (it is about 18.1 tokens) than without cheap talk treatment (it is about 16.3 tokens) and average coefficient of variation (CV) for communication treatments is about 22% and for without communication treatment it is around 26%. So, under complete information contest, we do not find any substantial heterogeneity in contribution decisions across all treatments.

Now we focus our attention into the incomplete information contests. For the advantage groups, under both cost and value heterogeneity, the mean player contribution is significantly lower in cheap talk communication treatment (wilcox p-values are $1.178e^{-06}$ and $9.274e^{-13}$ respectively. Also the variation for the communication treatment are around 40%, which is relatively high. The

significant variation in contribution decisions by advantage groups across communication treatment under incomplete information is indicated by the high value of CV. We also find similar trend of mean player contribution in case of disadvantage groups under incomplete information i.e. the mean player contribution is significantly lower in cheap talk communication treatment (respective wilcox p-values for cost and value heterogeneity are 0.001364 and 0.0009022. But variation in contribution decisions by disadvantage groups across all treatments are not that much high.

To compare the effect of information environment (complete or incomplete information) as well as communication protocol (cheap talk or no cheap talk), we run a series of linear regressions as shown in Table 9 and Table 10. For regression result presented in 9 we also include control variables for controlling for players' age, work experience and English level. The dummy variable 'advantage_group' quantifies the effect of having higher prize valuation or lower unit cost effort. The regression results confirms that being in the advantage group significantly impact the individual player's contribution level. For complete information, it increases the mean contribution significantly by 1.12 tokens when there is no cheap talk communication but it decreases the mean contribution significantly by 1.15 tokens when there is cheap talk communication. Contrasting to this scenario, being in the advantage group significantly reduces the mean contribution level for incomplete information. The deceases in presence of cheap talk is more than the decrease without cheap talk.

Result 8:

In contests with cheap talk, individuals in the advantage group contribute significantly less in contests with incomplete information than with complete information.

In Table 10 , we study the comparison between complete and incomplete information contests.Here the dummy variable 'cheap_talk' measure the impact of employing cost-less pre-play communication (cheap talk) on individual contribution level. It takes value 1 if cheap talk is available , else it takes value 0. We find a fully contrasting picture here. For complete information contests, it increases the average contribution level significantly, where as, for incomplete information it significantly decreases average contribution level in compare to without cheap talk contests. Though the effect of 'advantage_group' is negative but it is significant in case of incomplete information contests but not for complete information contests.

In summary, the regression analyses confirm that the cheap talk have an immediate effect on contributions of individuals. particularly, it reduces overbidding significantly in case of information asymmetry i.e. for incomplete information contests.

Table 9: Regression table for player contribution

	Dependent variable: player contribution			
	com info		incom info	
	without chat	with chat	without chat	with chat
factor(heterogenity.type)value	1.357***	0.494**	0.288	0.413
	(0.204)	(0.225)	(0.263)	(0.338)
advantage_group	1.116***	−1.154***	−0.324	−1.778***
	(0.206)	(0.241)	(0.200)	(0.380)
player.age	−0.644***	1.819***	0.390***	0.061
	(0.121)	(0.047)	(0.077)	(0.171)
player.workexperience	0.094*	0.104***	−0.270***	0.018
	(0.055)	(0.017)	(0.050)	(0.106)
player.english	−0.001	0.005	−0.008*	−0.028***
	(0.005)	(0.006)	(0.004)	(0.008)
Constant	27.229***	−19.919***	10.780***	16.921***
	(2.675)	(1.024)	(1.612)	(3.718)
Num. obs.	900	1050	900	900

Note: *p<0.1; **p<0.05; ***p<0.01.
Clustering done at session level.
'com info' and 'incom info' indicate complete and incomplete information respectively.

Table 10: Regression table for effect of information on player contribution

	Dependent variable: player contribution	
	com info	incom info
cheap_talk	0.580***	−1.799***
	(0.157)	(0.185)
factor(heterogenity.type)value	0.893***	0.351
	(0.192)	(0.249)
advantage_group	−0.184	−1.029***
	(0.192)	(0.198)
player.age	0.839***	0.289***
	(0.051)	(0.092)
player.workexperience	0.163***	−0.124***
	(0.021)	(0.047)
player.english	0.023***	−0.024***
	(0.003)	(0.005)
Constant	−2.396**	13.919***
	(1.119)	(2.095)
Num. obs.	1950	1800

Note: *p<0.1; **p<0.05; ***p<0.01.
Clustering done at session level.
'com info' and 'incom info' indicate complete and incomplete information respectively.

Result 9a:

In complete information contests, individuals contribute significantly more when cost-less pre-play communication (cheap talk) is allowed.

Result 9b:

In incomplete information contests, individuals contribute significantly less when cost-less pre-play

communication (cheap talk) is allowed.

Result 10a:

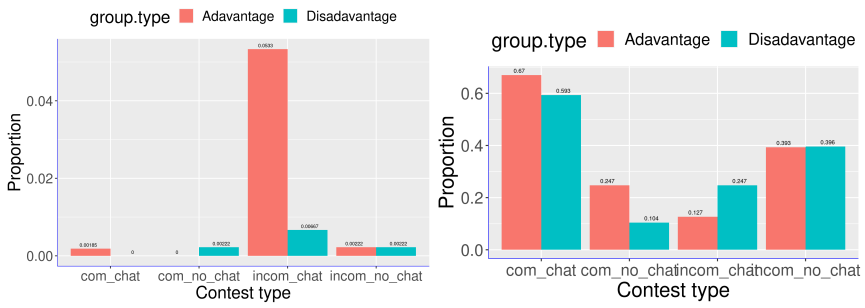
In complete information contests, individuals in the advantage groups contribute significantly more when no cost-less pre-play communication (cheap talk) is allowed and significantly less when cost-less pre-play communication (cheap talk) is allowed in compare to the individuals in disadvantage groups.

Result 10b:

In incomplete information contests, individuals in the advantage groups contribute significantly less when cost-less pre-play communication (cheap talk) is allowed in compare to the individuals in disadvantage groups.

6.6 Free riding behavior:

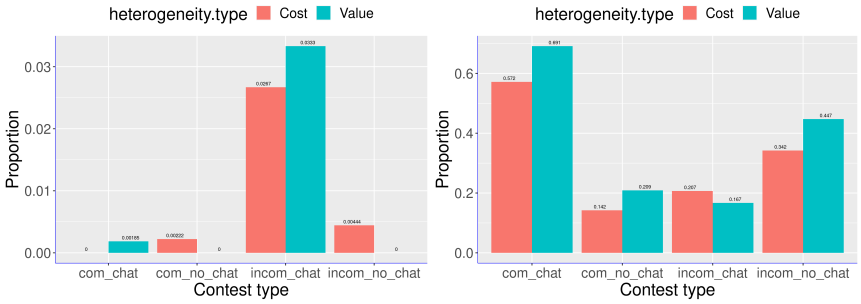
In this section we analyze the results of proportion of zero and full contribution in our context experiment. Panel A and B in Figure 15 show zero and full contribution respectively for advantage groups and disadvantage groups. Figure 16 depicts for cost and value heterogeneity in panel A and B respectively. In complete information contests, difference in proportion of zero contribution under cheap talk treatment across advantage and disadvantage groups are negligible and almost equal to zero. But for incomplete information, this difference is high. From Figure 15, we find under cheap talk treatment, there is comparatively higher proportion of zero contribution for advantage groups. Similar trend is observed in case of full contribution. Under cheap talk treatment, proportion of full contribution is higher for both the groups. Among these two groups (advantage and disadvantage), players in the advantage group contributes their whole endowment more often.



(a) Zero Contribution

(b) Full Contribution

Figure 15: Proportion of zero & full contribution of players across contests with advantage and disadvantage groups



(a) Zero Contribution

(b) Full Contribution

Figure 16: Proportion of zero & full contribution of players across contests with different source of heterogeneity

Under cheap talk treatment, the same pattern for zero and full contribution is followed in Figure 16 for both cost and value heterogeneity. The only difference we observe is that, under cost and value heterogeneity, players within the disadvantage groups contribute none or whole of their endowment more often than players within the advantage groups. from here we can conclude that implementation of cheap talk in no way mitigates the free riding phenomenon in contests.

Result 11:

Cheap talk can not improve the free riding behavior in contests.

7 Concluding Remarks:

The primary objective of this paper is to study the impact of cheap talk communication on group-level effort in a heterogeneous inter-group competition under incomplete information and compare it with the complete information scenario. In theory, incomplete information over the opponent's type (advantaged or disadvantaged) causes contest-level effort to be higher under "uneven" contests between an advantaged and disadvantaged group, and lower under "even" contests where both teams are advantaged, or both are disadvantaged. We find some support for the theory, but only for uneven contests and only when the source of advantage is a lower effort cost or a higher prize value for the winning team.

Earlier research has shown that in games of coordination, communication fosters better coordination and demonstrates effectiveness in terms of efficiency. This study shows that this can not be generalised in heterogeneous group contest. Specifically, in perfect substitute group contest, we find that introduction of cheap talk communication between groups have opposite impact with respect to the information condition. Cheap talk communication protocol fails to achieve better coordination in case of complete information which stands in stark contrast to earlier research findings ([81], [24], [75] but this communication protocol fosters better coordination in case of incomplete information contests which is our key addition to the literature of communication in coordination games. Considering the source of heterogeneity, we find that under cost heterogeneity, communication can significantly reduce aggregate group effort in incomplete information contests but fails to do the same in case of complete information contests; thus resulting less wasteful rent seeking under incomplete information. And under value heterogeneity, a complete opposite result prevails.

Free-riding incentives provide one reason why behavior in the group size treatments is differentiated from the cost and value treatments, which in turn could explain the empirical differences observed across these sources-of advantage. Our analysis does find that those in group size treatments are more likely to free-ride. While effort from advantaged groups is unexpectedly high in uneven contests under complete information, effort from disadvantaged groups is as well. This could be the result of players in a disadvantaged team learning to best-respond in our repeated game setting, or perhaps those prone to free-riding on large teams "make up" for this socially undesirable behavior by over-expending when placed on a smaller team.

The experimental discourse has widely applied Tullock model of rent seeking to influence various instances of public policy. On this note, our findings have preliminary relevance for contest design. When competing groups are asymmetric (uneven contests), according to theory incomplete information causes only a wasteful increase in efforts (lower efficiency) as there are no significant changes in the probability of winning for advantaged and disadvantaged groups. Thus, if the organizer cares about efficiency, they can engender this by promoting communication among the group members.

Although our experimental analysis particularly consideration of incomplete information is an addition to the growing literature of communication as it has not been studied widely till now, more studies involving other type of group aggregation mechanism (such as, best shot or weakest link) can check robustness of our findings. So, we claim from our analysis that cheap talk communication can be better coordination enriching mechanism when there is information asymmetry but this can be treated as a general effective mechanism.

A Proof of Lemma 3.1:

$$\frac{c_D v}{(c_A+c_D)^2} - \frac{v}{8}\left[\frac{4c_A}{(c_A+c_D)^2} + \frac{1}{c_D}\right] = \frac{vc_A - vc_D}{2(c_A+c_D)^2} + \frac{v}{8c_D}$$
$$= \frac{vc_A - vc_D}{2(c_A+c_D)^2} + \frac{vc_D}{8{c_D}^2}$$
$$= \frac{vc_D}{8{c_D}^2} - \frac{vc_D - vc_A}{2(c_A+c_D)^2}$$

Now by definition of advantaged and disadvantaged group:

$$c_A < c_D$$
$$\longrightarrow (c_A+c_D)^2 < (c_D+c_D)^2 = 4{c_D}^2$$
$$\longrightarrow \frac{v}{2(c_D+c_D)^2} > \frac{v}{8{c_D}^2}$$
$$\longrightarrow \frac{vc_D}{8{c_D}^2} - \frac{vc_D - vc_A}{2(c_A+c_D)^2} > 0$$
$$\longrightarrow \frac{v}{8c_D} - \frac{vc_D - vc_A}{2(c_A+c_D)^2} > 0$$

This proves our lemma 3.1.

B Proof of Lemma 3.2:

$$\frac{v_D}{8c}\left[\frac{4v_A}{(v_A+v_D)^2} + \frac{1}{v_D}\right] - \frac{{v_A}^2.v_D}{c(v_A+v_D)^2}$$
$$= \frac{1}{8c} + \frac{v_D}{c}\left[\frac{v_A}{2(v_A+v_D)^2} - \frac{2{v_A}^2}{2(v_A+v_D)^2}\right.$$
$$= \frac{1}{8c} + \frac{v_D}{c}\left[\frac{v_A - 2{v_A}^2}{2(v_A+v_D)^2}\right.$$
$$= \frac{1}{8c} + \frac{1}{c}\left[\frac{v_A v_D - 2{v_A}^2 v_D}{2(v_A+v_D)^2}\right.$$
$$= \frac{1}{c}\left[\frac{4(v_A+v_D)^2 - 4v_A v_D - 8{v_A}^2 v_D}{8(v_A+v_D)^2}\right]$$
$$= \frac{1}{c}\left[\frac{4(v_A+v_D)^2 - 4v_A v_D(1-2v_A)}{8(v_A+v_D)^2}\right]$$

Now if $v_A > \frac{1}{2}$, *then* $(1-2v_A) < 0$.
This implies that

$$4v_Av_D(1-2v_A)8(v_A+v_D)^2<0$$

$$\longrightarrow -4v_Av_D(1-2v_A)8(v_A+v_D)^2>0$$

$$\longrightarrow \frac{1}{c}[\frac{4(v_A+v_D)^2-4v_Av_D(1-2v_A)}{8(v_A+v_D)^2}]>0$$

$$\longrightarrow \frac{v_D}{8c}[\frac{4v_A}{(v_A+v_D)^2}+\frac{1}{v_D}]-\frac{{v_A}^2.v_D}{c(v_A+v_D)^2}>0$$

Similarly, assuming $v_D > \frac{1}{2}$, this holds for the disadvantage group as well.
This proves our lemma 3.2.

C Proof of Propositions

C.A Proof of Proposition 4.1:

For incomplete information, contests, the rent dissipation of the advantage group $(RD_{A_c}) = \frac{{x_{A_c}}^{**}}{v} = \frac{\frac{1}{8}v\left[\frac{4c_A}{(c_A+c_D)^2}+\frac{1}{c_D}\right]}{v} = \frac{1}{8}\left[\frac{4c_A}{(c_A+c_D)^2}+\frac{1}{c_D}\right]$.

Similarly, for complete information, contests, the rent dissipation of the advantage group $(RD_A) = \frac{{x_A}^{*}}{v} = \frac{c_D}{(c_D+c_A)^2}$.

We will prove our proposition by contradiction.

Let us assume that for the advantage group, the rent dissipation is higher for incomplete information in comparison to complete information scenario. That means the following:

$$
\begin{aligned}
RD_{A_c} > RD_A \\
&\longrightarrow \frac{1}{8}\left[\frac{4c_A}{(c_A+c_D)^2}+\frac{1}{c_D}\right] > \frac{c_D}{(c_D+c_A)^2} \\
&\longrightarrow \frac{c_A}{2(c_A+c_D)^2}-\frac{c_D}{(c_A+c_D)^2}+\frac{1}{8c_D} > 0 \\
&\longrightarrow \frac{c_A-2c_D}{2(c_A+c_D)^2} > -\frac{1}{8c_D} \\
&\longrightarrow \frac{2c_D-c_A}{2(c_A+c_D)^2} < \frac{1}{8c_D} \\
&\longrightarrow \frac{2c_D-c_A}{(c_A+c_D)^2} < \frac{1}{4c_D} \\
&\longrightarrow \frac{c_D(2-\frac{c_A}{c_D})}{{c_D}^2(1+\frac{c_A}{c_D})^2} < \frac{1}{4c_D} \\
&\longrightarrow 4(2-\frac{c_A}{c_D}) < (1+\frac{c_A}{c_D})^2 \\
&\longrightarrow 8-4\frac{c_A}{c_D} < (\frac{c_A}{c_D})^2+2.\frac{c_A}{c_D}+1 \\
&\longrightarrow 1+(\frac{c_A}{c_D})^2+2.\frac{c_A}{c_D}-8+4\frac{c_A}{c_D} > 0 \\
&\longrightarrow (\frac{c_A}{c_D})^2+6\frac{c_A}{c_D}-7 > 0 \\
&\longrightarrow (\frac{c_A}{c_D})^2+2.\frac{c_A}{c_D}.3+9-16 > 0 \\
&\longrightarrow (\frac{c_A}{c_D}+3)^2 > 16 \\
&\longrightarrow \frac{c_A}{c_D}+3 > \sqrt{(16)} \\
&\longrightarrow \frac{c_A}{c_D}+3 > 4 \\
&\longrightarrow \frac{c_A}{c_D} > 1 \\
&\longrightarrow c_A > c_D
\end{aligned}
$$

But this is a contradiction since by definition of our advantage and disadvantage group, $c_A < c_D$.

Thus we prove our proposition 1.

C.B Proof of Proposition 4.2:

Let us assume that for the advantage group, the rent dissipation is higher for incomplete information in comparison to complete information scenario. That means the following:

$$
\begin{aligned}
&RD_{D_c} > RD_D \\
&\longrightarrow \frac{1}{8}\left[\frac{4c_D}{(c_A+c_D)^2}+\frac{1}{c_A}\right] > \frac{c_A}{(c_D+c_A)^2} \\
&\longrightarrow \frac{c_D}{2(c_A+c_D)^2}-\frac{c_A}{(c_A+c_D)^2}+\frac{1}{8c_A} > 0 \\
&\longrightarrow \frac{c_D-2c_A}{2(c_A+c_D)^2} > -\frac{1}{8c_A} \\
&\longrightarrow \frac{2c_A-c_D}{2(c_A+c_D)^2} < \frac{1}{8c_A} \\
&\longrightarrow \frac{2c_A-c_D}{(c_A+c_D)^2} < \frac{1}{4c_A} \\
&\longrightarrow \frac{c_A(2-\frac{c_D}{c_A})}{{c_A}^2(1+\frac{c_D}{c_A})^2} < \frac{1}{4c_A} \\
&\longrightarrow 4(2-\frac{c_D}{c_A}) < (1+\frac{c_D}{c_A})^2 \\
&\longrightarrow 8-4\frac{c_D}{c_A} < (\frac{c_A}{c_D})^2+2.\frac{c_A}{c_D}+1 \\
&\longrightarrow 1+(\frac{c_D}{c_A})^2+2.\frac{c_D}{c_A}-8+4\frac{c_D}{c_A} > 0 \\
&\longrightarrow (\frac{c_D}{c_A})^2+6\frac{c_D}{c_A}-7 > 0 \\
&\longrightarrow (\frac{c_D}{c_A})^2+2.\frac{c_D}{c_A}.3+9-16 > 0 \\
&\longrightarrow (\frac{c_D}{c_A}+3)^2 > 16 \\
&\longrightarrow \frac{c_D}{c_A}+3 > \sqrt{16} \\
&\longrightarrow \frac{c_D}{c_A}+3 > 4 \\
&\longrightarrow \frac{c_D}{c_A} > 1 \\
&\longrightarrow c_D > c_A
\end{aligned}
$$

This completes the proof.

C.C Proof of Proposition 4.3:

For incomplete information, contests, the rent dissipation of the advantage group $(RD_{A_v}{}^{**}) = \frac{x_{A_v}{}^{**}}{v} = \frac{v_D}{8cv_A}\left[\frac{4v_A}{(v_A+v_D)^2}+\frac{1}{v_D}\right]$.

For complete information, contests, the rent dissipation of the advantage group $(RD_{A_v}) = \frac{x_{A_v}}{v} = \frac{v_A v_D}{c(v_A+v_D)^2}$.

For $RD_{A_v}{}^{**} > RD_{A_v}$*, we have the following:*

$$
\begin{aligned}
RD_{A_v}{}^{**} > RD_{A_v} \\
&\longrightarrow \frac{v_D}{8v_A}\left[\frac{4v_A}{(v_A+v_D)^2}+\frac{1}{v_D}\right] > \frac{v_Av_D}{(v_A+v_D)^2} \\
&\longrightarrow \frac{v_D}{8v_A}\left[\frac{4v_Av_D+(v_A+v_D)^2}{v_D(v_A+v_D)^2}\right] > \frac{v_Av_D}{(v_A+v_D)^2} \\
&\longrightarrow \frac{v_D}{2}+\frac{(v_A+v_D)^2}{8v_A} > v_Av_D \\
&\longrightarrow \frac{1}{2v_A}+\frac{1}{8v_D}(1+\frac{v_D}{v_A})^2 > 1
\end{aligned}
$$

This completes our proof.

C.D Proof of Proposition 4.4:

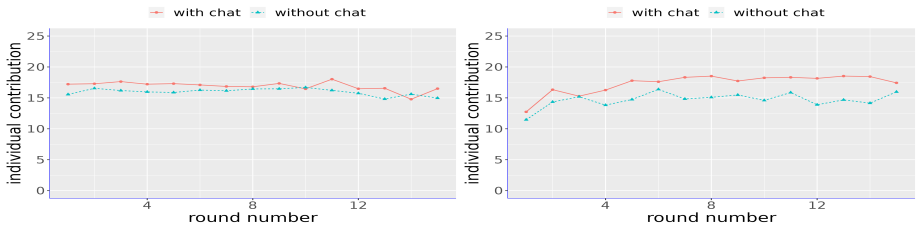
Similar to the proof of proposition 3, we can show that:

$$
\begin{aligned}
RD_{D_v}{}^{**} > RD_{D_v} \\
&\longrightarrow \frac{v_A}{8v_D}\left[\frac{4v_D}{(v_A+v_D)^2}+\frac{1}{v_A}\right] > \frac{v_Av_D}{(v_A+v_D)^2} \\
&\longrightarrow \frac{v_A}{8v_D}\left[\frac{4v_Av_D+(v_A+v_D)^2}{v_A(v_A+v_D)^2}\right] > \frac{v_Av_D}{(v_A+v_D)^2} \\
&\longrightarrow \frac{v_A}{2}+\frac{(v_A+v_D)^2}{8v_D} > v_Av_D \\
&\longrightarrow \frac{1}{2v_D}+\frac{1}{8v_A}(1+\frac{v_A}{v_D})^2 > 1
\end{aligned}
$$

This completes the proof.

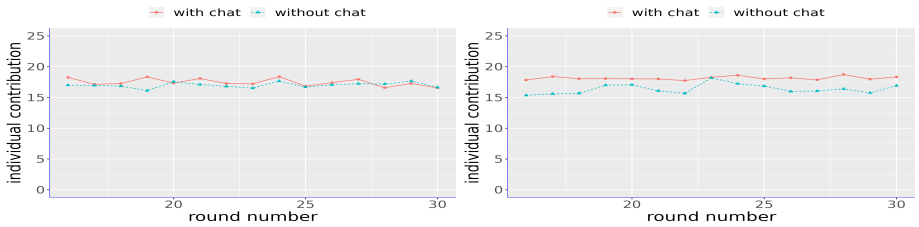
D Additional Tables and figures:

D.A Figures:



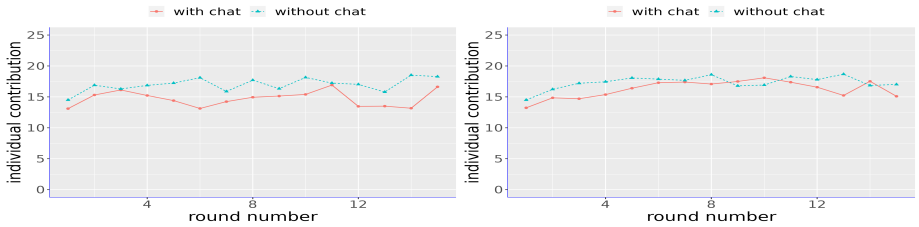
(a) Advantage group (b) Disadvantage group

Figure 17: Average player contribution in complete information group contest under cost heterogeneity



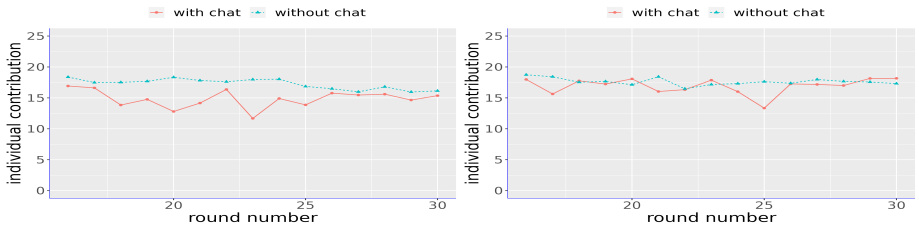
(a) Advantage group (b) Disadvantage group

Figure 18: Average player contribution in complete information group contest under value heterogeneity



(a) Advantage group (b) Disadvantage group

Figure 19: Average player contribution in complete information group contest under cost heterogeneity



(a) Advantage group (b) Disadvantage group

Figure 20: Average player contribution in complete information group contest under value heterogeneity

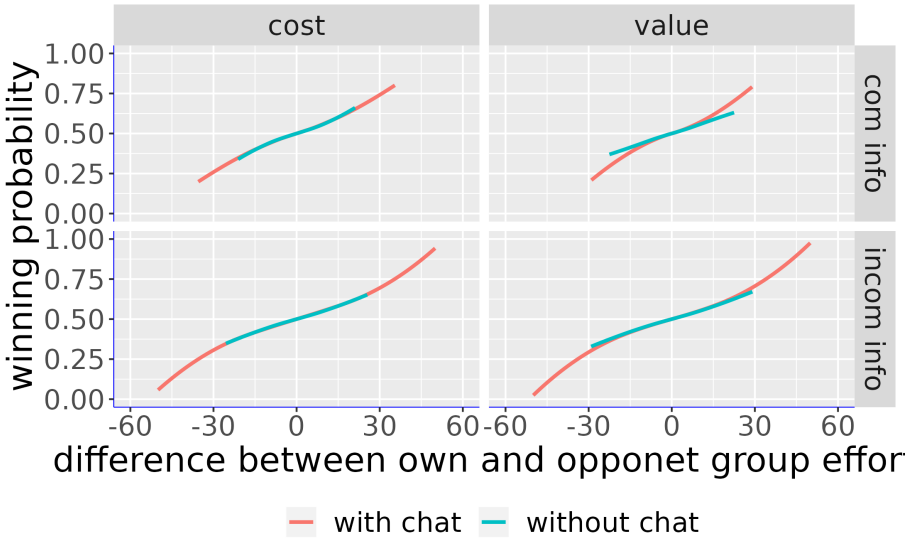


Figure 21: Graph of winning probability

D.A.1 Tables:

Table 11: Session wise details of the experiment

session code	game type	No. of participants
ujjzwjzv	incom_info_with_chat	12
pv68brwp	group contest	48
u9cuit5s	com_info_wo_chat	12
jc539zu2	incom_info_wo_chat	12
10t4fbwf	incom_info_with_chat	12
i6697y47	com_info_with_chat	12
TOTAL		126

Table 12: Description of data

Variable Name	Description
Dependent variable	
Group contribution	Total points contributed by all group members
Player contribution	Points contributed by the participant, 0 to 20 points
Treatment variables	
cheap talk	= 1 if group members are allowed to chat; 0 otherwise
value	= 1 for value heterogeneity; 0 otherwise
incomplete	= 1 for incompete information contest; 0 otherwise
adtantage_group	= 1 for advantaged groups; 0 otherwise
Control variables	
player.age	Participant age, as recorded
player.workexperience	=1 if the participant had partaken in a prior economics experiment; 0 otherwise
player.english	Participant eglish level, between 0 to 100

Table 13: Summary statistics of contribution(effort) by treatment

Treatment			Average individual effort	Average individual minimum effort	Average group effort	Average waste effort
Complete information	**Cost heterogeneity**	**Cheap talk**	17.1 (5.12)	14.9 (6.83)	51.3 (12.4)	32.6 (16.0)
		No cheap talk	15.3 (5.07)	11.9 (5.65)	46.0 (11.2)	27.2 (13.3)
	Value heterogeneity	**Cheap talk**	17.8 (4.76)	16.0 (6.48)	53.4 (11.6)	34.6 (15.6)
		No cheap talk	16.7 (4.38)	13.6 (5.52)	50.1 (8.83)	31.3 (12.2)
Incomplete information	**Cost heterogeneity**	**Cheap talk**	15.5 (5.16)	11.9 (5.85)	46.4 (11.0)	24.6 (13.8)
		No cheap talk	17.2 (3.76)	14.3 (4.35)	51.5 (7.19)	29.6 (12.7)
	Value heterogeneity	**Cheap talk**	15.9 (5.23)	13.0 (5.74)	47.7 (12.4)	47.5 (12.4)
		No cheap talk	17.4 (3.84)	14.7 (4.73)	52.3 (7.88)	52.1 (7.88)
Note: Standard errors are shown in parentheses						

Table 14: Group effort comparison between treatments

SOURCE OF HETEROGE-NEITY	**GROUP TYPE**	**CONTEST INFORMATION**	**MEAN PLAYER CONTRIBUTION**		**WILCOX P-VALUE**
			WITH CHEAP TALK	**WITHOUT CHEAP TALK**	
COST	ADAVANTAGE	COMPLETE INFORMATION	50.7 (14.00)	47.9 (9.56)	8.53E-06
VALUE	ADVANTAGE	COMPLETE INFORMATION	52.4 (13.60)	51 (8.20)	2.48E-07
COST	ADVANTAGE	INCOMPLETE INFORMATION	44.1 (12.30)	51 (7.35)	0.0005123
VALUE	ADVANTAGE	INCOMPLETE INFORMATION	44.6 (14.40)	51.8 (7.92)	0.0008405
COST	DISADVANTAGE	COMPLETE INFORMATION	51.9 (10.70)	44.1 (12.40)	1.22E-07
VALUE	DISADVANTAGE	COMPLETE INFORMATION	54.4 (9.19)	49.1 (9.38)	3.65E-09
COST	DISADVANTAGE	INCOMPLETE INFORMATION	48.7 (8.92)	52 (7.05)	0.02492
VALUE	DISADVANTAGE	INCOMPLETE INFORMATION	50.8 (9.11)	52.9 (7.86)	0.01032
Note: values in parenthesis are standard deviations					

Table 15: Group effort comparison between advantage and disadvantage groups

Source of heterogeneity	**Information type**	**Communication type**	**Mean group contribution**		**Wilcoxon P-value**
			Advantage group	**Disadvantage group**	
Cost	Complete	With chat	50.70441 (2.224808)	51.93797 (4.774957)	0.02104
	Complete	Without chat	47.89806 (1.653539)	44.09704 (3.504631)	0.0003355
	Incomplete	With chat	44.13022 (3.815320)	48.73838 (4.213539)	0.00397
	Incomplete	Without chat	50.95443 (3.310156)	51.97773 (3.162018)	0.2093
Value	Complete	With chat	52.36658 (1.8204443)	54.41093 (0.8428036)	0.002726
	Complete	Without chat	50.99869 (1.290953)	49.14103 (2.366542)	0.009033
	Incomplete	With chat	44.55101 (4.280435)	50.79829 (3.911315)	0.0001805
	Incomplete	Without chat	51.7960 (2.511530)	52.8648 (1.731736)	0.2093
Note: standard errors are given in the parenthesis					

Table 16: Individual effort comparison between treatments

Source of heterogeneity	Group type	Information type	Mean group contribution		Wilcoxon P-value
			Without cheap talk	With cheap talk	
Cost	Advantage	Complete	15.96602 (4.837538) [30.29896]	16.90147 (16.90147) [30.29896]	4.328e-13
Value	Advantage	Complete	16.99956 (4.436073) [26.09522]	17.45553 (5.306536) [30.40032]	1.608e-10
Cost	Advantage	Incomplete	16.98481 (3.87680) [22.82510]	14.71007 (5.90996) [40.17627]	1.178e-06
Value	Advantage	Incomplete	17.26533 (4.131288) [23.92823]	14.85034 (5.860893) [39.46639]	9.274e-13
Cost	Disadvantage	Complete	14.69901 (5.217042) [35.49247]	17.31266 (17.31266) [24.83679]	2.2e-16
Value	Disadvantage	Complete	16.38034 (4.306658) [26.29162]	18.13698 (4.120078) [22.71645]	2.2e-16
Cost	Disadvantage	Incomplete	17.32591 (3.642454) [21.02316]	16.24613 (16.24613) [25.62414]	0.001364
Value	Disadvantage	Incomplete	17.62160 (3.521486) [19.98392]	16.93276 (16.93276) [25.31052]	0.0009022
Note: standard errors are given in the parenthesis coefficient of variations (in percentage) are given in square brackets					

Table 17: Proportion of Zero and full contribution for different group type in contests

Contest type	Proportion of contribution level		Percentage of contribution level		Group type
	Zero contribution	Full contribution	Zero contribution	Full contribution	
com_info_with_chat	0.00185	0.67	0.185	67	Adavantage
com_info_wo_chat	0	0.247	0	24.7	Adavantage
incom_info_with_chat	0.0533	0.127	5.33	12.7	Adavantage
incom_info_wo_chat	0.00222	0.393	0.222	39.3	Adavantage
com_info_with_chat	0	0.593	0	59.3	Disadavantage
com_info_wo_chat	0.00222	0.104	0.222	10.4	Disadavantage
incom_info_with_chat	0.00667	0.247	0.667	24.7	Disadavantage
incom_info_wo_chat	0.00222	0.396	0.222	39.6	Disadavantage

Table 18: Effect of cheap talk

	Dependent variable: group contribution	
	Information Type	
	Com info	Incom info
cheap_talk	−2.275	−2.275
	(4.081)	(4.081)
value	2.316**	2.316**
	(1.002)	(1.002)
incomplete	−1.990	−1.990
	(4.168)	(4.168)
value:incomplete	−1.685	−1.685
	(2.307)	(2.307)
Constant	50.670***	50.670***
	(3.529)	(3.529)

Note: *p<0.1; **p<0.05; ***p<0.01.
Clustering done at group level.
'Com info' and 'Incom info' complete information and incomplete information respectively.

Table 19: Proportion of Zero and full contribution for different source of heterogeneity in contests

Contest type	**Proportion of contribution level**		**Percentage of contribution level**		**Group type**
	Zero contribution	**Full contribution**	**Zero contribution**	**Full contribution**	
com_info_with_chat	0	0.572	0	57.2	Cost
com_info_wo_chat	0.00222	0.142	0.222	14.2	Cost
incom_info_with_chat	0.0267	0.207	2.67	20.7	Cost
incom_info_wo_chat	0.00444	0.342	0.444	34.2	Cost
com_info_with_chat	0.00185	0.691	0.185	69.1	Value
com_info_wo_chat	0	0.209	0	20.9	Value
incom_info_with_chat	0.0333	0.167	3.33	16.7	Value
incom_info_wo_chat	0	0.447	0	44.7	Value

E Experimental instruction and other steps:

E.A Experimental instructions (Welcome Note):

Thank you for participating in this experimental activity today. You have earned 100 rupees. This amount will be added to your final earnings today in this activity.

In this activity,you will be able to earn points according to your decision and the decisions of other participants. Each point you earn will be paid at 0.1 rupees per point.

When you start the activity by selecting the :next" button, you agree that the data about your decisions will be used for research purposes only. this information will be anonymous i.e. it will not be possible to link your decision data with any information that would allow you to be identified. Additionally, we request you to carefully read and fill out the informed consent form given to you.

Participation in this research will require a maximum of one hour of your time, in which it is not allowed to carry out other simultaneous activities or receive help from other people.

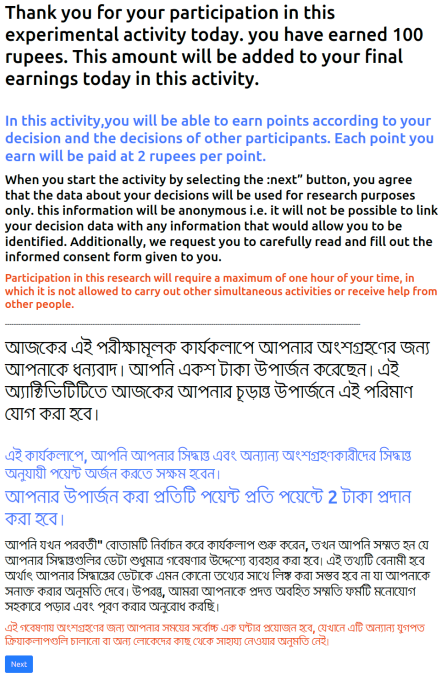
E.B Experimental instructions (General Instruction) :

Welcome to our experiment! It is very important that you carefully read and understand the following instructions. If you have any questions please raise your hand. We will then come to you and answer them. Communication with other participants before and during the experiment is prohibited. If you violate this rule, you will have to leave the experiment and will not receive any payments.

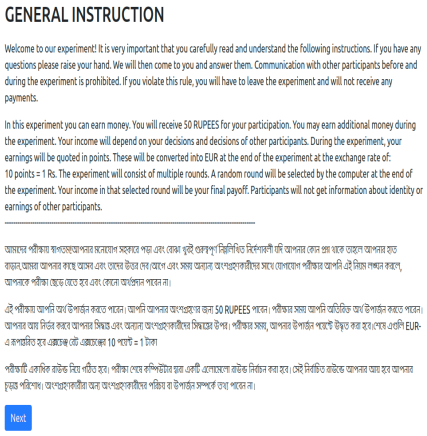
In this experiment you can earn money. You will receive 50 RUPEES for your participation. You may earn additional money during the experiment. Your income will depend on your decision and decision of other participants. During the experiment, your earnings will be quoted in points. These will be converted into EUR at the end of the experiment at the exchange rate of:

10 points = 1 Rs.

The experiment will consist of multiple rounds. A random round will be selected by the computer at the end of experiment. Your income in that selected round will be your final payoff. Participants will not get information about identity or earnings of other participants.



(a) Welcome Note



(b) General Instruction

Figure 22: Welcome Note and General Instruction page from the experiment

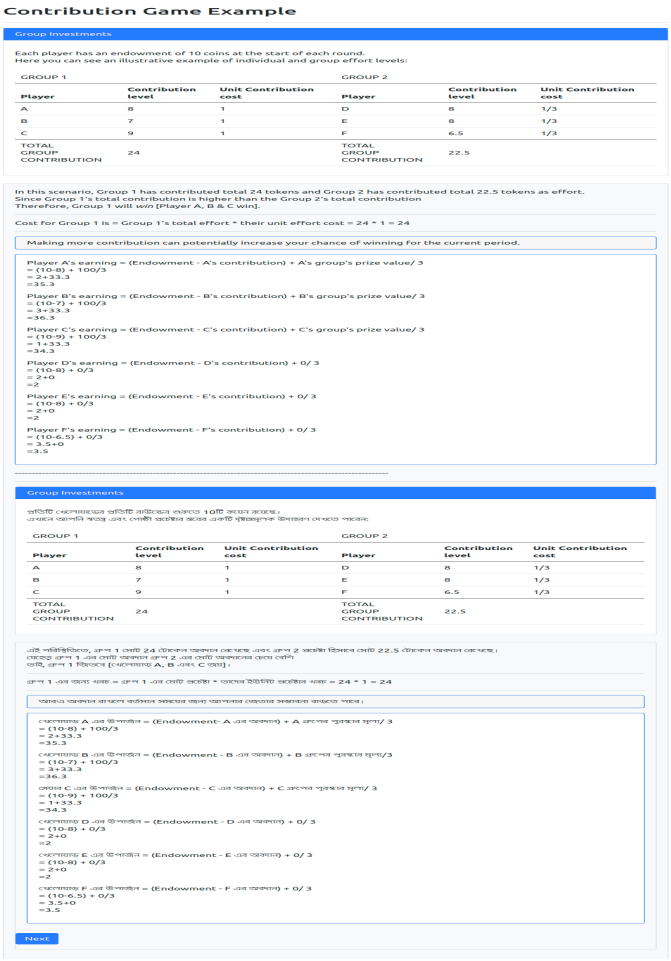
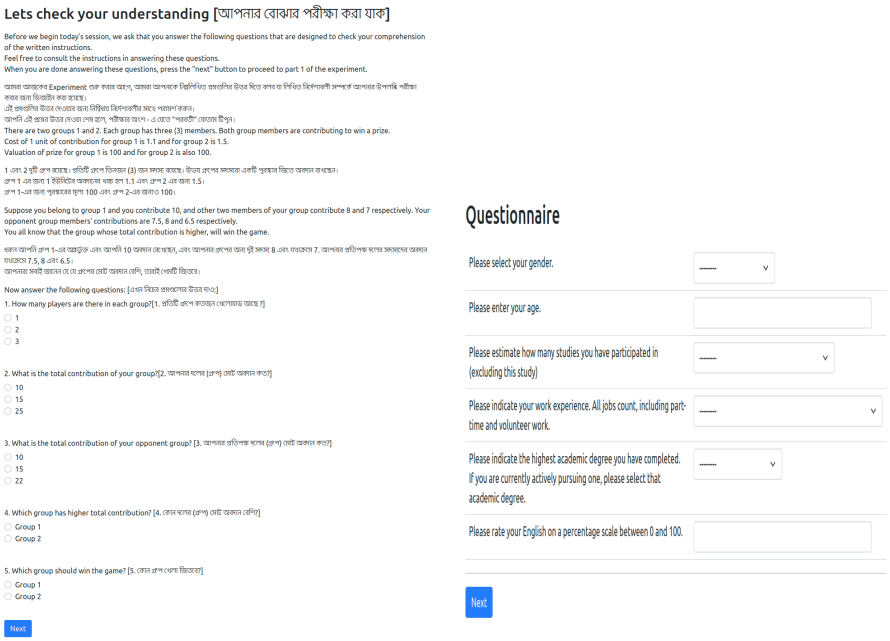


Figure 23: Experimental instructions (Game Description)



(a) Attention Check (b) Demographic Questions

Figure 24: Attention Check and Demographic Questions page from the experiment

References

[1] *Abbink, K., Brandts, J., Herrmann, B., and Orzen, H. (2010). Intergroup conflict and intra-group punishment in an experimental contest game.* American Economic Review, *100(1):420–47.*

[2] *Ahn, T., Isaac, R. M., and Salmon, T. C. (2011). Rent seeking in groups.* International Journal of Industrial Organization, *29(1):116–125.*

[3] *Baik, K. H. (1993). Effort levels in contests: The public-good prize case.* Economics Letters, *41(4):363–367.*

[4] *Baik, K. H. (2008). Contests with group-specific public-good prizes.* Social choice and Welfare, *30(1):103–117.*

[5] *Baik, K. H., Kim, I.-G., and Na, S. (2001). Bidding for a group-specific public-good prize.* Journal of Public Economics, *82(3):415–429.*

[6] *Barbieri, S., Kovenock, D., Malueg, D. A., and Topolyan, I. (2019). Group contests with private information and the "weakest link".* Games and Economic Behavior, *118:382–411.*

[7] *Barbieri, S. and Malueg, D. A. (2016). Private-information group contests: Best-shot competition.* Games and Economic Behavior, *98:219–234.*

[8] Bhattacharya, P. (2016). Inter-team contests with power differential. Journal of Economic Behavior & Organization*, 132:157–175.*

[9] Blume, A. and Ortmann, A. (2007). The effects of costless pre-play communication: Experimental evidence from games with pareto-ranked equilibria. Journal of Economic theory*, 132(1):274–290.*

[10] Blume, A. and Ortmann, A. (2017). The effects of costless pre-play communication: Experimental evidence from games with pareto ranked equilibria. Journal of Economic Theory*, 132:274–290.*

[11] Bohm, R., Rusch, H., and Baron, J. (2020). The psychology of intergroup conflict: A review of theories and measures. Journal of Economic Behavior and Organization*, 178(C):947–962.*

[12] Boosey, L., Brookins, P., and Ryvkin, D. (2017). Contests with group size uncertainty: Experimental evidence. Games and Economic Behavior*, 105:212–229.*

[13] Bornstein, G. (1992). The free-rider problem in intergroup conflicts over step-level and continuous public goods. Journal of Personality and Social Psychology*, 62(4):597.*

[14] Bornstein, G., Gneezy, U., and Nagel, R. (2002). The effect of intergroup competition on group coordination: An experimental study. Games and Economic Behavior*, 41(1):1–25.*

[15] Bornstein, G., Rapoport, A., Kerpel, L., and Katz, T. (1989). Within-and between-group communication in intergroup competition for public goods. Journal of Experimental Social Psychology*, 25(5):422–436.*

[16] Brandts, J. and Cooper, D. J. (2007). It's what you say, not what you pay: An experimental study of manager-employee relationships in overcoming coordination failure. Journal of the European Economic Association*, 5(6):1223–1268.*

[17] Brookins, P., Lightle, J. P., and Ryvkin, D. (2018). Sorting and communication in weak-link group contests. Journal of Economic Behavior & Organization*, 152:64–80.*

[18] Brookins, P., Lightle, J. P., Ryvkin, D., et al. (2015). The effects of communication and sorting on output in heterogeneous weak-link group contests. Technical report.

[19] Brookins, P. and Ryvkin, D. (2014). An experimental study of bidding in contests of incomplete information. Experimental Economics*, 17:245–261.*

[20] Cai, T., Jiao, Q., and Zheng, J. (2017). Asymmetric rent-seeking contests with multiple agents of two types.

[21] Cason, T. N., Sheremeta, R. M., and Zhang, J. (2012). Communication and efficiency in competitive coordination games. Games and Economic Behavior*, 76(1):26–43.*

[22] Cason, T. N., Sheremeta, R. M., and Zhang, J. (2015). Asymmetric and endogenous communication in competition between groups. Available at SSRN 2556536*.*

[23] Cason Timothy, N., Sheremeta, R. M., and Zhang, J. (2012). Communication and efficiency in competitive coordination games. Games and Economic Behavior*, 76:26–43.*

[24] Cason Timothy, N., Sheremeta, R. M., and Zhang, J. (2017). Asymmetric and endogenous within group communication in competitive coordination games. Experimental Economics*, 20:946–972.*

[25] Charness, G. (2000). Self-serving cheap talk: A test of aumann's conjecture. Games and Economic Behavior, *33(2):177–194.*

[26] Charness, G. and Grosskopf, B. (2004a). What makes cheap talk effective? experimental evidence. Economics Letters, *83(3):383–389.*

[27] Charness, G. and Grosskopf, B. (2004b). What makes cheap talk effective: Experimental evidence. Economics Letters, *83:383–389.*

[28] Chen, D. L., Schonger, M., and Wickens, C. (2016). otree—an open-source platform for laboratory, online, and field experiments. Journal of Behavioral and Experimental Finance, *9:88–97.*

[29] Choi, J. P., Chowdhury, S. M., and Kim, J. (2016). Group contests with internal conflict and power asymmetry. The Scandinavian Journal of Economics, *118(4):816–840.*

[30] Chopra, V., Nguyen, H. M., Vossler, C. A., et al. (2020). Heterogeneous group contests with incomplete information. Technical report.

[31] Chowdhury, S., Lee, D., and Sheremeta, R. (2001). Top guns may not fire: best-shot group contests with group-specific public good prizes. Journal of Economic Behavior and Organization, *92:94–103.*

[32] Chowdhury, S. M. and Moffatt, P. G. (2017). Overbidding and heterogeneous behavior in contest experiments: A comment on the endowment effect. Journal of Economic Surveys, *31(2):572–576.*

[33] Cooper, R., De Jong, D., Forsythe, R., and Ross, T. (1992a). Communication in coordination games. Quarterly Journal of Economics, *107:739–771.*

[34] Cooper, R., DeJong, D. V., Forsythe, R., and Ross, T. W. (1992b). Communication in coordination games. The Quarterly Journal of Economics, *107(2):739–771.*

[35] Cubel, M. and Sanchez-Pages, S. (2014). Inequality in conflicts. Technical report, Working Paper.

[36] Dechenaux, E., Kovenock, D., and Sheremeta, R. M. (2015). A survey of experimental research on contests, all-pay auctions and tournaments. Experimental Economics, *18:609–669.*

[37] Duffy, J. and Feltovich, N. (2002). Do actions speak louder than words? observation vs. cheap talk as coordination devices. Games and Economic behavior, *39(1):1–27.*

[38] Eisenkopf, G. (2014). The impact of management incentives in intergroup contests. European Economic Review, *67:42–61.*

[39] Eliaz, K. and Wu, Q. (2018). A simple model of competition between teams. Journal of Economic Theory, *176:372–392.*

[40] Erev, I., Bornstein, G., and Galili, R. (1993). Constructive intergroup competition as a solution to the free rider problem: a field experiment. Journal of Experimental Social Psychology, *29:463–478.*

[41] Esteban, J. and Ray, D. (2001). Collective action and the group size paradox. American political science review, *95(3):663–672.*

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

[43] Fey, M. (2008). Rent-seeking contests with incomplete information. Public Choice*, 135(3):225–236.*

[44] Fiske, S. T. (2002). What we know now about bias and intergroup conflict, the problem of the century. Current Directions in Psychological Science*, 11(4):123–128.*

[45] Flamand, S. and Troumpounis, O. (2015). Prize-sharing rules in collective rent seeking. In Companion to the political economy of rent seeking*. Edward Elgar Publishing.*

[46] Garfinkel, M. R. and Skaperdas, S. (2007). Economics of conflict: An overview. Handbook of defense economics*, 2:649–709.*

[47] Gunnthorsdottir, A. and Rapoport, A. (2006). Egalitarian vs. proportional profit-sharing rules in multi-level collective action problems. Organizational Behavior and Human Decision Processes*, 101:184–199.*

[48] Hurley, T. M. and Shogren, J. F. (1998a). Asymmetric information contests. European Journal of Political Economy*, 14(4):645–665.*

[49] Hurley, T. M. and Shogren, J. F. (1998b). Effort levels in a cournot nash contest with asymmetric information. Journal of Public Economics*, 69(2):195–210.*

[50] Katz, E., Nitzan, S., and Rosenberg, J. (1990). Rent-seeking for pure public goods. Public Choice*, 65(1):49–60.*

[51] Kimborough, E. O. and Sheremeta, R. M. (2013). Side-payments and the costs of conflict. International Journal of Industrial Organization*, 31(3):278–286.*

[52] Konrad, K. A. et al. (2009). Strategy and dynamics in contests. OUP Catalogue.

[53] Krueger, A. O. (1974). The political economy of the rent-seeking society. American Economic Review*, 64(3):291–303.*

[54] Kugler, T., Rapoport, A., and Pazy, A. (2010). Public good provision in inter-team conflicts: effects of asymmetry and profit-sharing rule. Journal of Behavioral Decision Making*, 23(4):421–438.*

[55] Lee, D. (2012a). Weakest-link contest with group-specific public good prizes. European Journal of Political Economy*, 28:238–248.*

[56] Lee, D. (2012b). Weakest-link contests with group-specific public good prizes. European Journal of Political Economy*, 28(2):238–248.*

[57] Leibbrandt, A. and Sääksvuori, L. (2012). Communication in intergroup conflicts. European Economic Review*, 56(6):1136–1147.*

[58] Lopez, A. and Johnson, D. (2020). The war puzzle: explaining conflict in international relations. Journal of Economic Behavior and Organization*, 178:983–997.*

[59] Millner, E. L. and Pratt, M. D. (1989). An experimental investigation of efficient rent-seeking. Public Choice*, 62(2):139–151.*

[60] Millner, E. L. and Pratt, M. D. (1991). Risk aversion and rent-seeking: An extension and some experimental evidence. Public Choice*, 69(1):81–92.*

[61] Nalbantian, H. R. and Schotter, A. (1997). Productivity under group incentives: An experimental study. The American economic review*, pages 314–341.*

[62] Nitzan, S. (1991a). Collective rent dissipation. The Economic Journal*, 101(409):1522–1534.*

[63] Nitzan, S. (1991b). Rent-seeking with non-identical sharing rules. Public Choice*, 71(1):43–50.*

[64] Nitzan, S. and Ueda, K. (2011). Prize sharing in collective contests. European Economic Review*, 55(5):678–687.*

[65] Nitzan, S. and Ueda, K. (2014). Intra-group heterogeneity in collective contests. Social choice and Welfare*, 43(1):219–238.*

[66] Nitzan, S. and Ueda, K. (2018). Selective incentives and intragroup heterogeneity in collective contests. Journal of Public Economic Theory*, 20(4):477–498.*

[67] Nti, K. O. (1998). Effort and performance in group contests. European Journal of Political Economy*, 14(4):769–781.*

[68] Olson, M. (1965). Logic of collective action: Public goods and the theory of groups (Harvard economic studies. v. 124)*. Harvard University Press.*

[69] Rapoport, A. and Bornstein, G. (1987). Intergroup competition for the provision of binary public goods. Psychological Review*, 94(3):291.*

[70] Rusch, H. and Gavrilets, S. (2020). The logic of animal intergroup conflict: a review. Journal of Economic Behavior and Organization*, 178:1014–1030.*

[71] Ryvkin, D. (2010). Contests with private costs: Beyond two players. European Journal of Political Economy*, 26(4):558–567.*

[72] Ryvkin, D. (2011). The optimal sorting of players in contests between groups. Games and Economic Behavior*, 73(2):564–572.*

[73] Ryvkin, D. (2013). Heterogeneity of players and aggregate effort in contests. Journal of Economics & Management Strategy*, 22(4):728–743.*

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

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

[76] Sheremeta, R. M. (2011b). Perfect-substitutes, best-shot, and weakest-link contests between groups. Korean Economic Review*, 27:5–32.*

[77] Sheremeta, R. M. (2013). Overbidding and heterogeneous behavior in contest experiments. A Collection of Surveys on Market Experiments*, pages 109–134.*

[78] Sheremeta, R. M. (2017). Behavior in group contests: A review of experimental research. Journal of Economic Surveys*, 32(3):683–704.*

[79] Sheremeta, R. M. (2018a). Behavior in group contests: A review of experimental research. Journal of Economic Surveys*, 32(3):683–704.*

[80] Sheremeta, R. M. (2018b). Experimental research on contests. Available at SSRN 3260263.

[81] Sutter, M. and Strassmair, C. (2009). Communication, cooperation and collusion in team tournaments—an experimental study. Games and Economic Behavior*, 66(1):506–525.*

[82] Trevisan, F. (2020). Optimal prize allocations in group contests. Social Choice and Welfare*, 55(3):431–451.*

[83] Tullock, G. (1980). Efficient rent seekingin jm buchanan, rd tollison & g. tullock eds.

[84] Van Dijk, F.and Sonnemans, J. and van Winden, F. (2001). Incentives systems in a real effort experiment. European Economic Review*, 45:187–203.*

[85] Van Huyck, J. B., Battalio, R. C., and Beil, R. O. (1993). Asset markets as an equilibrium selection mechanism: Coordination failure, game form auctions, and tacit communication. Games and Economic Behavior*, 5(3):485–504.*

[86] Vasudha, C., Nguyen, H. M., and Vossler, C. A. (2023). Who are we up against: Heterogeneous group contests with incomplete information. SSRN Electronic Journal.

[87] Wärneryd, K. (2012). Multi-player contests with asymmetric information. Economic Theory*, 51(2):277–287.*

[88] Wasser, C. (2013). Incomplete information in rent-seeking contests. Economic Theory*, 53(1):239–268.*

[89] Zhang, J. (2012). Communication in asymmetric group competition over public goods.