CONTESTS WITHIN AND BETWEEN GROUPS: THEORY AND EXPERIMENT[†]

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ABSTRACT. This paper examines behavior (theoretically and experimentally) in a two-stage group contest where the first stage comprises of intra-group contests, followed by an inter-group contest in the second stage. Rewards accrue only to the members of the winning group in the inter-group contest, with the winners of the intra-group contest within that group receiving a greater reward. The model generates a discouragement effect, where losers from the first stage exert less effort in the second stage than winners. In contrast to previous frameworks of sequential contests, we show that a prior win may be disadvantageous, generating lower profits for first stage winners as compared to losers. This implies that incentives for participation in the first stage may not always be present. We also consider exogenous asymmetry between groups arising from a biased contest success function in the second stage. We show that although the asymmetry occurs in the second stage, the effect of the asymmetry plays out in the first stage, with the intra-group contest being more intense within the advantaged group. Experimental results find broad support for the qualitative predictions of the model. However, we find that relative overcontribution in the second stage by losers is higher than by winners of the first stage, implying that losers bear a higher burden of the group contribution than deemed strategic.

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1. Introduction

Many competitive activities in everyday life take place between groups. While individuals within a group share broad political or commercial interests with their group members, they are often divided over specific issues within the superordinate group goal. For example, while a supporter of the Democratic Party may prefer any candidate from her party over any Republican candidate to win the presidential election, she may favor a particular Democrat candidate over all others. In such situations, contests often occur sequentially, with an *intra*-group contest determining allocation of rewards among group members, followed by an *inter*-group contest to determine the group that wins. A common observation in such contests is that rivals from the intra-group stage often unite to compete collectively against the out-group, indicating a strong superordinate group goal.

Consider the behavior of partisans in the US presidential election. In the primaries, interest groups lobby for their preferred candidate within their preferred political party to determine the presidential nominee. Think of this as the intra-group contest where supporters of Elizabeth Warren and Joe Biden are in competing subgroups but share the superordinate group identity of being a Democrat. However, in the general election, which is the inter-group stage, interest groups supporting candidates who lost the primary often transfer their support to the nominee from their party to unite against a common rival. Toby Neugebauer, a wealthy energy investor, who donated $10 million toward Ted Cruz's campaign, donated to the Trump campaign in the general election. In an online survey, Dunham et al. [2018] finds that 55% of Democrats supporting Bernie Sanders in the 2016 primaries, intended to vote for Clinton in the presidential election. The common goal of defeating the Republican candidate seemed to undo intra-party animosities within the Democrat camp.[1] Indeed, most losing primary candidates endorse their party's eventual nominee.[2] Faculty recruiting within a department also has a similar structure, where each department first selects a field and then competes collectively with another department for a candidate. Similar examples abound in R&D competitions, where firms conduct contests among their employees to select ideas that, subsequently, *all* employees work on to win a patent race.[3]

[1] Henderson et al. [2010] notes that supporters of losing primary candidates in the 2008 elections tended to 'come home' to their party's eventual candidate.

[2] In the last four presidential elections, 91.7% of the top two losing candidates (by vote share in each party's primary) has endorsed the nominee in the general election.

[3] A similar example is the Hurricane Sandy Design competition, where ten teams comprising of engineers, architects, and scientists competed to have their proposals to rebuild hurricane-affected regions implemented. Prior to this, sub-teams within each team had submitted multiple proposals from which one per team was chosen by a panel of judges.

As diverse the above examples may seem, they can all be classified under a two-stage contest where rivals from an earlier stage can choose to unite against a common out-group. The aim of this paper is to characterize optimal individual effort in such two-stage contests. In particular, we explore the following contest structure – individuals belong to a *group* and within a group to a sub-group, that we refer to as a *faction*. In the first stage, an *intra-group* contest decides a winning faction in each group. In the second stage, all factions in each group collectively compete with other groups in an *inter-group* contest to determine the winning group. In our setting a benefit accrues to an individual only if his group wins the inter-group contest. Importantly, the magnitude of the benefit depends on the outcome of the intra-group contest - an individual belonging to a faction that won the intra-group stage receives a greater reward than an individual in the losing faction, with both rewards being strictly positive. Note that the intra-group contest determines rewards prospectively, since whether or not a group wins is only realized in the second stage.

In addition, we explore how relative position differences arising from an early win or loss affects behavior. In the second stage, individuals need to cooperate under the shadow of past rivalry. How do winners and losers from the first stage coordinate effort within their group when acting collectively in the second stage? To identify whether behavioral considerations affect effort provision we test the main predictions of the model using a controlled laboratory experiment.

Our analysis also encompasses contests that are biased, favoring one group over others. Biased contests can arise when the contest is discriminatory or one group has an exogenous advantage. For example, Lee [2001] shows that incumbency has a significantly positive causal effect on the probability that the incumbent party will succeed, by about 0.40. Hence, members of an incumbent party have a greater likelihood of being elected to office than a challenger, given the same lobbying efforts. We consider bias in the second stage (inter-group contest), asking how such asymmetry affects effort in both stages.

In our model, individuals play Tullock [1980] game in each stage. In the first stage, individuals decide how much effort to expend for the intra-group contest. After individuals learn the outcome of the first stage, they participate in the second stage, where individuals choose how much effort to expend for the inter-group contest. The restrictions on the effort-cost function are minimal - increasing and strictly convex. We introduce bias in the contest through the contest success function in the inter-group stage i.e., groups are advantaged or disadvantaged.

The unique equilibrium exhibits the following key features. Individual effort in the inter-group contest depends on the outcome in the prior intra-group stage – individuals belonging to the winning faction from the intra-group stage exert more effort than those who belong to factions that lost. This is intuitive, since members in winning factions have a higher expected reward than those who lost in their group. However, the higher effort is associated with higher costs and, consequently, the payoff from a prior win may not always be greater than from a loss. Our analysis highlights that incentives for participation may be absent in the initial stage, even when individuals prefer different alternatives within a group.

In equilibrium, the bias in the inter-group contest success function, surprisingly, does not affect effort provision in the inter-group contest, but rather in the intra-group contest. In the inter-group contest, individuals' effort decisions are independent of their group position, i.e., individuals in the winning (losing) faction in the advantaged group exert identical effort to the individuals in the winning (losing) faction in the disadvantaged group. However, in the intra-group stage, individuals in advantaged groups exert more effort as compared to disadvantaged groups. Hence, the intra-group contest, if measured by the amount of costly effort exerted, is more intense within the advantaged group. Furthermore, we find that the standard result that heterogeneity among contestants reduces total effort, may not necessarily hold in our setting. Under certain cost conditions, across both stages of the contest, total effort exerted can be greater in a contest between asymmetric groups rather than symmetric groups. This result is driven by the greater intensity of the intra-group contest among the factions of the advantaged group.

We follow up our theoretical results with an experiment. Our experiment includes two treatments - *Symmetric* and *Asymmetric* - that vary whether or not the contest is biased. In addition to providing a direct test for the predictions of our model, our experiment is expressly aimed to understand two aspects of behavior. Given the path-dependent valuations across stages, individuals have to think ahead about the second stage when exerting effort in the first stage. Comparing intra-group contest expenditure across the symmetric and asymmetric settings directly allows us to observe whether individuals are forward-looking and internalize a future advantage/disadvantage. We additionally elicit beliefs that allow us to observe how individuals learn and respond to the dynamic incentives of the game. Our second focus is to understand how groups coordinate effort among members who were rivals in the past. In particular, are there behavioral spillovers between stages that make losers of the first stage unwilling to cooperate in the second-stage?

We find that participants respond to a relative advantage (disadvantage) in the future, by exerting higher (lower) effort in the first stage, thus responding correctly to the dynamic incentives. We also find individuals easily respond to the reward incentives as individuals belonging to winning factions from the intra-group stage exert significantly higher effort in the inter-group contest than those in losing factions. However, the share of group contribution borne by intra-group winners is lower than theoretical predictions. This observation holds for both the symmetric and asymmetric treatments. This suggests that the behavioral response to a prior win versus a prior loss may not be fully accounted for by strategic considerations. We explore possible reasons for relative over-contribution by losers.

In our model, winning the first stage provides access to higher expected rewards. Similar incentives have been explored by Megidish and Sela [2014] and Clark and Nilssen [2018] where a win in the first stage creates an advantage by either increasing the valuation of winning, or increasing the productivity of effort in the second stage. However, these papers are confined to analyzing situations where competitors repeatedly compete with the same opponent. In these papers, there is always a 'win advantage' as in equilibrium winners from the first stage receive a higher payoff than losers. In contrast, the present paper focuses on situations where winners and losers of the first stage are on the same side of the second stage contest and shows that the 'win advantage' may not always be present.

The rest of the paper is organized as follows. We present a review of the literature in Section 2. We describe the model in Section 3 and solve it to characterize the equilibrium expenditure levels. In Section 4, we describe our experimental procedures. Section 5 provides results from our experiment. Section 6 concludes.

2. Related Literature

The work in this paper is broadly related to several strands of research. One, it is related to the literature on dynamic contests. In modeling dynamic contests, economists focus primarily on two contest structures - the sequential multi-battle contest (Klumpp and Polborn [2006], Mago and Sheremeta [2017]) and the hierarchical elimination contest (Rosen [1986], Baik and Lee [2000], Risse [2011], Fu and Lu [2012], Gradstein and Konrad [1999]). In the former, individuals repeatedly compete with the same opponent and the winner of the overall contest is a function of the outcome of all battles. Hence, every battle involves the same set of competitors. In elimination contests, winners in each stage survive to the next stage and losers are eliminated from subsequent play. Hence the contest narrows down the set of active contestants.[4]

Another variant of elimination contests fought among groups also consists of two stages (Katz and Tokatlidu [1996], Konrad [2004]). In the first stage, several groups of contestants compete for a reward. The winning group receives the reward and the second stage determines how the reward is shared among the winning group members through an intra-group contest.[5] Hence, elimination group contests incorporate an inter-group contest followed by an

[4]Many papers model the US primary system as an elimination contest. Indeed, it is better modeled as an elimination tournament from the perspective of candidates. However, once one takes on the perspective of voters and partisans, the non-elimination nature of the contest becomes apparent.

[5]Wärneryd [1998] and Müller and Wärneryd [2001] use this structure to consider allocation of resources within federations and allocation of cash flow inside organizations, respectively.

intra-group contest in the winning group. While the allocation of the reward within a group is decided *ex-post* in elimination contests, in our setting it is decided *ex-ante*.[6] There is also an existing body of literature that considers both intra- and inter-group contests, but in a simultaneous setting. Hausken [2005] and Münster [2007] focus on the relative incidence of within and between group conflict expenditure as a function of group size and decisiveness of each contest, respectively. Choi et al. [2016] extends this framework to include heterogeneous groups and complementarity in members' group conflict efforts.

Our paper is also related to the extensive literature on asymmetry in static contests. Papers have studied various sources of asymmetry arising from differences in endowments (Heap et al. [2015]); costs of effort (Schotter and Weigelt [1992]); contest success function (Fonseca [2009], Bhattacharya [2016]). Fallucchi and Ramalingam [2017] compare different sources of asymmetry and find that competitive effort is greatest in the presence of asymmetric contest success functions. In comparison, the evidence on the effect of asymmetry in dynamic contests is relatively scarce. Stracke and Sunde [2014] provide theoretical results for a difference in cost of effort in individual elimination tournaments. Lackner et al. [2015] document evidence consistent with this model in a field study with professional basketball players. They show that relative differences in effort cost affect behavior in the current and preceding stage of an elimination tournament. Our results, therefore, supplement these papers, by extending the analysis to study asymmetry in contest success functions in a previously unstudied version of dynamic contest.

Finally, our paper is more generally related to the large literature on group contests (Sheremeta [2018]). The theoretical literature examining strategic behavior in group contests has focused on group size, the sharing rule, the contest success function (CSF), among others, as determinants of the intensity of conflict. Our work attempts to build on this by introducing a new model of group contest and testing it using a laboratory experiment.

3. Model

Consider two *groups* $g \in \{A, B\}$ - each consisting of two equal-sized sub-groups, referred to as *factions* $f \in \{1, 2\}$. Each faction f consists of n risk-neutral individuals indexed by i = 1,...,n.[7] Each individual, i, has a positive and commonly known endowment of ω and

[6] Stein and Rapoport [2004]) compares these two temporal structures in an individual contest and finds them to be strategically different i.e., elicit different effort and best responses.

[7] Think of the groups A and B as being "interest groups", where members of Group $A(B)$ prefer alternative $A(B)$ to $B(A)$, where A and B are alternatives available to society and can be competing public projects or different political parties in office. Within each faction, individuals are homogeneous.

participates in two sequential contests by deciding how much of her endowment to contribute toward winning each contest. The two contests proceed in the following way.

Stage 1 is an *intra-group* contest - factions within each group compete to determine prospectively the rewards each will receive in case the group wins in the next stage. Individuals in each faction independently and simultaneously contribute $x_{gfi} \geq 0$, where g, f, and i index the group, faction, and individual, respectively. Individual i's cost of contribution is $C(x_{gfi})$, which leaves i a remaining budget of $\omega - C(x_{gfi})$ for the next stage. We assume $C(.)$ is a twice continuously differentiable function with $C_x(0) = 0$, $C_x(z) > 0$ for $z > 0$, and $C_{xx}(.) > 0$.[8] The probability of faction f winning the intra-group contest in group g depends on the aggregate contributions of members in faction f and the aggregate contribution of the competing faction f'. It is given by the lottery contest success function (Tullock [1980], Katz et al. [1990])

$$p_{gf} = \begin{cases} \frac{X_{gf}}{X_{gf}+X_{gf'}}, & \text{if } X_{gf} > 0 \text{ or } X_{gf'} > 0, \\ \frac{1}{2}, & \text{otherwise,} \end{cases} \tag{1}$$

where $X_{gf} = \sum_{i \in gf} x_{gfi}$ for $g = A, B$ and $f = 1, 2$.[9] The outcome of the first contest becomes public information before the second contest begins.

Stage 2 is an *inter-group* contest - groups A and B compete to determine the winning group. Individuals simultaneously contribute $y_{gfi} \geq 0$ toward the group contest, incurring cost $C(y_{gfi})$.[10] The probability of group g winning the group contest is given by

$$p_g = \begin{cases} \frac{\alpha_g Y_g}{\alpha_g Y_g + \alpha_{g'} Y_{g'}}, & \text{if } Y_g > 0 \text{ or } Y_{g'} > 0, \\ \frac{\alpha_g}{\alpha_g + \alpha_{g'}}, & \text{otherwise,} \end{cases} \tag{2}$$

where $Y_g = \sum_{i \in g} y_{gfi}$, for $g, g' = A, B$ and $g \neq g'$. α_g is a strictly positive constant that captures the effectiveness of each unit of contribution for group g. $\alpha_g \neq \alpha_{g'}$ implies that the group contest is asymmetric, favoring the group with a higher α.[11]

[8]Contributions by individuals may consist of personal effort, time, or funds. Convex cost of contribution captures the increasing marginal utility loss from foregoing the consumption of other goods. See Esteban and Ray [2001] for a discussion on why assuming convex costs is appropriate for collective action problems.

[9]The lottery contest function is continuous and satisfies several easily interpretable axioms like anonymity and homogeneity of degree zero (Skaperdas [1996]). Münster [2009] axiomatizes the group contest success function.

[10]We assume separability of costs across stages, i.e., in line with Rosen (1986) there is no carryover of costs between stages.

[11]Klumpp and Polborn [2006], Beviá and Corchón [2013], Bhattacharya [2016] are among many papers introducing heterogeneity between contestants through the contest success function. See Gradstein [1995], for axiomatic characterization of the asymmetric contest success function.

Rewards: Individuals only receive a reward if their group wins in the second stage. Individuals in the winning group can receive one of two rewards - v^H or v^L, where $0 < v^L < v^H$.[12] How the two rewards are allocated among the members of the winning group depends on the outcome of the first stage $-$ individuals who are members of the winning faction receive v^H, while individuals who lose the intra-group contest receive v^L. Individuals in the losing group receive zero, irrespective of their faction's outcome in the intra-group contest. The rewards are faction-specific public goods consumed nonexclusively by all members. Each individual's payoff is the sum of her reward and initial endowment, less her costs of contribution in both stages. Assuming risk neutrality, the expected payoff of individual i, in faction f, and group g is given by

$$\pi_{gfi} = p_g p_{gf}(v^H) + p_g(1 - p_{gf})v^L + \omega - C(x_{gfi}) - C(y_{gfi}) \tag{3}$$

In what follows, we assume that the endowment ω is sufficient, such that individuals are not resource constrained. We now characterize the subgame perfect equilibrium first and second stage contributions. We begin by examining the second stage - the inter-group contest. In the inter-group contest, the outcome of the intra-group contest is already determined. Hence, *within* groups, factions are no longer symmetric as one faction has won and the other has lost the prior contest. Each individual chooses her second stage contribution conditional on winning or losing the intra-group contest. In the propositions below, we characterize the Subgame Perfect Nash Equilibrium of the game.

Proposition 1. *For $g \in \{A, B\}$, let y^*_{gWi} and y^*_{gLi} be the equilibrium second-stage contribution of individuals in the winning and losing factions, respectively. Let Y^*_g be the equilibrium second-stage contribution of group g. If $C_y(0) = 0$, $C_y(r) > 0$ for all $r > 0$, and $C_{yy}() > 0$ hold, then:*

(i) The equilibrium second-stage contribution of each individual ***exists****; it is* ***unique*** *and* ***identical*** *across individuals within each faction. The equilibrium second-stage contribution of each individual solves:*

$$y^*_{gWi} = C_y^{-1}[\frac{v^H \alpha_g \alpha_{g'}}{(\alpha_g + \alpha_{g'})^2 Y^*_g}], \text{ and} \tag{4}$$

$$y^*_{gLi} = C_y^{-1}[\frac{v^L \alpha_g \alpha_{g'}}{(\alpha_g + \alpha_{g'})^2 Y^*_g}], \tag{5}$$

[12] Although we focus on a simplified framework where each group has two factions, our results can be extended to a more general framework with k factions. One possibility for rewards in a case with k factions, is that the winning faction receives v^H, while all other $k-1$ factions receive v^L. A second possibility is where each losing faction's reward value depends on the identity of the winning faction i.e., each losing faction receives $v^L_f(h)$, where h denotes the winning faction in the group. In this case, there will be $\frac{k(k-1)}{2}$ losing rewards for each pair of factions.

where $Y_g^* = n(y_{gWi}^* + y_{gLi}^*)$, *for* $g, g' \in \{A, B\}$, *and* $g' \neq g$.
(ii) The equilibrium group contributions are the same for the two groups, i.e., $Y_A^* = Y_B^* = Y^*$ *holds.*
(iii) $y_{AWi}^* = y_{BWj}^*$ *and* $y_{ALi}^* = y_{BLj}^*$ *hold for all* $i \in A$ *and* $j \in B$ *i.e., individual contributions in the winning (and losing) faction are identical across groups.*
(iv) $y_{gWi}^* > y_{gLj}^*$ *holds for all* $i, j \in g$, *and* $g = A, B$, *i.e., second-stage contribution by individuals in the winning faction is greater than by the individuals in the losing faction.*

Proof. See Appendix A.

Proposition 1 illustrates two features of equilibrium contributions in the inter-group contest. First, individual contributions vary within a group - individuals in factions that won the intra-group contest contribute more than individuals in factions that lost. This is intuitive, since the expected reward from winning the inter-group contest is higher for those who have won the intra-group contest as compared to those who lost in the intra-group contest. This result is analogous to the 'discouragement effect' found in sequential multi-battle contests where winners from early battles contribute more than losers in later battles due to higher continuation values (Klumpp and Polborn [2006], Konrad [2012], Mago and Sheremeta [2017]). However, unlike multi-battle contests, in our environment, the higher contributions by first stage winners do *not* translate to a higher likelihood of winning in the second stage as compared to losers, since the probability of success in the second stage depends on the *total* group contribution - which is the same for all group members, winners and losers of the first stage.

Second, although groups may be exogenously asymmetric (when $\alpha_g \neq \alpha_{g'}$), the total group contributions in the second stage are identical, irrespective of such asymmetries. To see the intuition, note that when an individual increases contribution, the marginal increase in probability that his group wins is equal to the marginal decrease in probability that the opponent group wins. Now, recall that the contest success function is homogeneous of degree zero i.e., equiproportionate increases in contributions by both groups leave the probability of success unaffected. Hence, when the advantaged group contributes less than the disadvantaged group, the marginal benefit from contributing an additional unit is greater for the advantaged than the disadvanatged group.[13] However, since the marginal cost of the advantaged group is less than the disadvantaged group, this contradicts equilibrium. Note that the identical group contributions guarantee that the advantaged group will have a higher probability of winning. This finding is identical to the result regarding the standard static contest with asymmetric contestants (Fonseca [2009], Bhattacharya [2016]).

[13]This follows directly from the Euler's Theorem and $\frac{\delta p_g}{\delta y_{gfi}} = -\frac{\delta p_{g'}}{\delta y_{gfi}} \cdot \frac{Y_g}{Y_{g'}} = \frac{\frac{p_g}{Y_g}}{\frac{p_g}{Y_{g'}}}$

Proposition 2. *(i) For all g, f, and i, the equilibrium first-stage contribution of each individual* ***exists****; it is* ***unique*** *and* ***identical*** *across individuals within each faction. The optimal first-stage contribution of each individual solves*

$$x^*_{gfi} = \begin{cases} C_x^{-1}[\frac{1}{4X^*_{gf}}\{\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})\}], & \textit{if } \frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi}) > 0, \\ 0, & \textit{otherwise,} \end{cases} \tag{6}$$

where y^*_{gWi} and y^*_{gLi} are determined by (4) and (5), and $X^*_{gf} = nx^*_{gfi}$.
(ii) Within each group, the aggregate contributions of each faction are the same. That is, $X^*_{A1} = X^*_{A2}$ and $X^*_{B1} = X^*_{B2}$ hold.
(iii) The advantaged group's factions contribute more in the intra-group contest. That is, if $\alpha_g > \alpha_{g'}$ and $x^*_{gfi} > 0$ holds, then $X^*_{gf} = X^*_{gf'} > X^*_{g'f} = X^*_{g'f'}$ hold for $f, f' = 1, 2$.

Proof. See Appendix A.

Note that whether individuals contribute in the first stage depends on whether $\frac{\alpha_g}{\alpha_g+\alpha_{g'}}(v^H - v^L) - C(y^*_{gWi}) + C(y^*_{gLi})$ is positive. This expression denotes the difference in future expected payoff from being in the winning faction and losing faction i.e., $\pi(y^*_{gWi}) - \pi(y^*_{gLi})$.[14] When the future expected payoff from being in the winning faction is greater than being in the losing faction, individuals will find it profitable to contribute toward winning the intra-group contest. If winning the intra-group contest does not yield higher expected profits, individuals will be disinclined to contribute. When individuals find it profitable to contribute, the magnitude of the difference between expected future profits determines how fierce the intra-group contest is.

On this point, a natural question is, "Are expected profits from winning the intra-group contest always greater than expected profits from losing it?" In other words, can we always expect $\frac{\alpha_g}{\alpha_g+\alpha_{g'}}(v^H - v^L) - C(y^*_{gWi}) + C(y^*_{gLi})$ to be positive, so individuals actively contribute in the first stage. Note 1 specifies the answer: "No."

Note 1: *Losing faction members' expected payoff in the second-stage can be strictly greater than the same for winning faction members. That is, $\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi}) \geq 0$ doesn't always hold.*

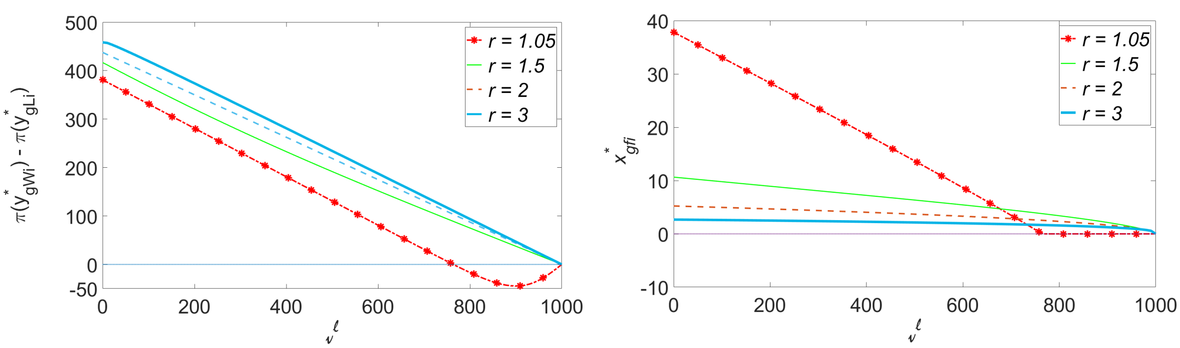
Note 1 is surprising at first, since it suggests that a prior win could be detrimental to final profits. The reason is that, although the expected reward from winning the intra-group stage is greater than losing it, the costs associated with a win are also higher than losing. Recall, by Proposition 1, that the winners of the intra-group stage contribute more in the inter-group contest. Thus, members of the losing faction can partially "free-ride" on the higher contribution of the winning faction members to win the inter-group contest. Hence, in equilibrium,

[14] $\pi(y^*_{gWi}) = \frac{\alpha_g}{\alpha_g+\alpha_{g'}}(v^H) - C(y^*_{gWi})$, and $\pi(y^*_{gLi}) = \frac{\alpha_g}{\alpha_g+\alpha_{g'}}(v^L) - C(y^*_{gLi})$

the expected payoff for members of factions that lost the intra-group stage can be higher than those who won.

This is in contrast to elimination contests where winners from a prior stage always earn higher expected profits than the losers. This is also in contrast to other structures of sequential contests, where a prior win is beneficial to the winning candidate as it increases the win probability in the next stage creating a strategic momentum. Our results are related to the well-known finding in static contests with intra-group heterogeneity that the contestant with the highest valuation in the group contributes the most, and therefore, may have a lower expected payoff than others who have a lower valuation of the prize (Baik [2008], Sheremeta [2011]). Unlike the considerations here, the valuation of the reward by each member is determined exogenously and not endogenously through a prior win or loss in the preceding stage. We provide an example that illustrates how expected future profit from winning compares to the expected future profit from losing the intra-group contest.

Example 1. *Consider cost functions of the form* $C(y) = y^r$*, where* $r > 1$*. Calculating* y^*_{gWi} *and* y^*_{gLi} *from Proposition 1 using* $C(y) = y^r$*, we get that when* $r \geq 2$*,* $\pi(y^*_{gWi}) - \pi(y^*_{gLi}) > 0$ *always holds. However, when* $1 < r < 2$*,* $\pi(y^*_{gWi}) - \pi(y^*_{gLi})$ *can be negative. Figure 1 illustrates this. We plot the difference in expected future profit between winning and losing the first stage and the optimal* x_{gfi} *for four values of* r*, and* $\alpha_g = \alpha'_g = 1$*,* $n = 1$*, and* $v^H = 1000$*.*



(a) Difference in Expected Future Profits (b) Equilibrium First Stage Contribution (x^*_{gfi})

FIGURE 1. Intra-Group Contest Contribution Decision

Proposition 2 also illustrates how contributions compare across factions and groups in the intra-group contest. First, *within* a group, contributions by competing factions are identical. This stems from the fact that factions in a group are symmetric in the intra-group contest. Second, *across* groups, factions contribute differently when there is asymmetry. Factions in groups that are disadvantaged (albeit in the next stage) contribute less than factions in groups that are advantaged. Hence the intra-group contest is 'less aggressive' in the disadvantaged group. This is because the continuation value from winning the intra-group stage is lower for individuals in disadvantaged groups than advantaged groups. Hence, although the asymmetry occurs in the second stage, the effect of the asymmetry plays out only in the first stage. This stands in contrast with the results of static contests, where asymmetric groups contribute the same. One implication of this is assuming incumbent parties face an advantage in being re-elected, the expenditure in the primaries will be higher for incumbent parties than challengers. This result mirrors the finding from Lackner et al. [2015] where the authors show that the expected relative strength of a future competitor affects behavior of professional basketball players in early stages. In contrast to Lackner et al. [2015], who study elimination contests where asymmetry arises from differential cost of effort, we study asymmetry with respect to the contest success function and get similar results in non-elimination contests.[15]

An important consideration among groups engaged in such contests is how closely aligned are the preferences of its factions. In our model, the reward to each member of the winning faction in the winning group is v^H, while the reward to each member of the losing faction in the winning group is v^L. When groups are polarized, such that factions within the group share little common interest, the reward v^L is small relative to v^H. On the other hand, if factions within the group have similar preferences, v^L will approach v^H. The next proposition highlights the relationship between v^L and contest expenditure.

Proposition 3. *Given v^H; y^*_{gLi} is strictly increasing while y^*_{gWi} is strictly decreasing in v^L. The former effect dominates, i.e., the aggregate second-stage group contribution Y^*_g is increasing in v^L.*

Proof. See Appendix A.

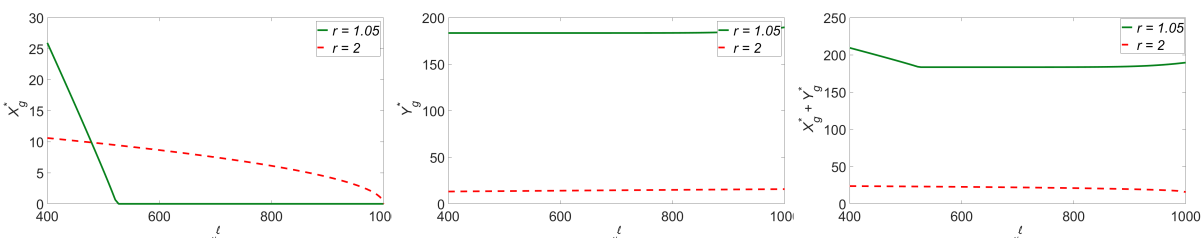
Intuitively, since v^L is the reward for which members of the losing faction are competing in the second stage, a higher v^L leads to higher second-stage contribution. As the group's second-stage contribution increases, members of the winning faction decrease their contribution because their contribution is substituted by the losing faction's contribution. Note that the substitution is not perfect. That is, the decrease in contributions by the winning faction is *less* than the increase in contribution by the losing faction. This is because an increase in v^L leads to an increase of the overall prize value of the contest.[16]

[15] Comparing total contributions (the sum of contributions of all members of both groups across both stages) across symmetric and asymmetric contests, we find for certain cost functions compatible with Propositions 1 and 2, total contribution can be higher in an asymmetric contest than a symmetric contest. Figure 9 in the Appendix, provides an illustrative example for the case where Asymmetric treatment generates higher total contributions for the cost function $C(z) = z^{1.05}$. Stracke and Sunde [2014] find a similar result in their study of dynamic incentive effects of heterogeneous costs among contestants in multi-stage elimination contests.

[16] A related question to consider is what happens when groups differ in v^L? Similar in spirit to Proposition 3, we find that if $v^L_g > v^L_{g'}$ holds, then: (a) $y^*_{gLi} > y^*_{g'Li}$; (b) $y^*_{gWi} < y^*_{g'Wi}$; and (c) $Y^*_g > Y^*_g$ hold. See Appendix Proposition 4.

The relation between an increase in v^L and first-stage contest expenditure is less straightforward. Recall that x^*_{gfi} is positively related to the difference in future expected payoff $\pi(y^*_{gWi}) - \pi(y^*_{gLi})$. Hence, how x^*_{gfi} changes with an increase in v^L will depend on how the difference in continuation values change. As v^L increases, in equilibrium, members of the losing faction gain from the direct effect of the increase in value of reward. There is also an indirect effect, since due to the higher expected reward, the members of the losing faction now contribute more in the inter-group contest (Proposition 3), incurring higher costs. So the sign of $\frac{d\pi(y^*_{gLi})}{dv^L}$ depends on how the costs and benefits change as v^L increases. For the members of the winning faction, there is only an indirect effect as an increase in v^L induces them to contribute less and, subsequently, incur less cost. Hence $\frac{d\pi(y^*_{gWi})}{dv^L} > 0$ always holds. So while the expected payoff from winning the first-stage will always increase as v^L increases, the direction of change in expected payoff from losing the first-stage is ambiguous. For general cost functions, it is impossible to derive an unambiguous direction for $\frac{d(\pi(y^*_{gWi})-\pi(y^*_{gLi}))}{dv^L}$. Referring back to Figure 1, we observe that x^*_{gfi} is weakly decreasing in v^L for the particular cost functions plotted. This is true for all cost functions of the form $C(x) = x^r, r > 1$. However, depending on the convexity of the cost function, if the expected payoff from losing falls as v^L increases, then x^*_{gfi} will *increase* as the group becomes more homogenous.

Note 2: x^*_{gfi} can increase or remain unchanged with an increase in v^L. We cannot rule out the possibility of a cost function such that x^*_{gfi} increases in v^L.[17]



(a) X^*_g (b) Y^*_g (c) $X^*_g + Y^*_g$

FIGURE 2. Total Group Contribution

As a final remark, we explore how *total* group contribution across both stages ($X^*_g + Y^*_g$) responds to an increase in v^L. We show that the change in total group contribution need not be monotonic, by providing examples of environments where total group contribution increases and decreases with v^L. Figure 2 shows how the group contributions in each stage (Panel (a) and (b)) as well as sum of both stages (Panel (c)) changes as v^L increases. We focus on cost functions $C(x) = x^r$, with r =1.05 (solid line) and r =2 (dashed line). We assume v^H=1000,

[17] A combined sufficient condition for x^*_{gfi} to increase with v^L is 1. $\frac{d\pi(y^*_{gLi})}{dv^L} \leq 0$ and 2. $x^*_{gfi} > 0$. While it is easy to construct a convex cost function where 1. holds, it is more involved to construct a case where both conditions hold.

$\alpha_g = \alpha'_g = 1$, and $n = 1$. For both cost conditions, as v^L increases, the value of the contest increases which imposes an upward pressure on total contribution. However, as v^L increases, it also reduces incentives for participating in the first stage. Hence, the total effect depends on the strength of the two opposing effects.

4. Experimental Design

To test the theoretical predictions of the model, we design a laboratory experiment where participants take part in a two-stage contest. While there are many aspects of the model one can test, we focus on two dimensions. First, given the dynamic nature of the contest, we wish to understand whether subjects think ahead to the inter-group interaction, when making decisions in the intra-group contest. Second, we wish to understand how subjects who were in competing factions in the intra-group contest, coordinate effort in the inter-group interaction.

Participants are randomly assigned to one of two groups - A or B. Within each group, participants are further randomly assigned to either faction **1** or faction **2**. Super-groups of eight are then formed with two members each from A**1**, A**2**, B**1** and B**2**. All interactions in a period take place within this super-group of eight participants. Participants' group and faction assignment, as well as super-groups were randomly drawn every period.

Each session consists of multiple periods. Every period consists of two stages. In the first stage (Intra-group Contest), the two factions within each group compete against each other. This means the two-member faction A**1** competes with the two-member faction A**2**. Similarly, the two-member faction B**1** competes with the two-member faction B**2**. In the second stage (Inter-group Contest), the four-member groups compete against each other.

We run two treatment conditions (*Symmetric* and *Asymmetric*) where the treatment variable is the *bias* in the group contest success function. In the Symmetric treatment, the contest success function in the second stage is *unbiased*, i.e., contributions by both groups A and B affect their respective probabilities of success identically ($\alpha_A = \alpha_B = 1$). In the Asymmetric condition, the contest success function is biased in favor of group A - contributions by group A are weighted twice as much as group B ($\alpha_A = 2, \alpha_B = 1$). Hence, group A is advantaged over group B.

In each period, participants are endowed with 300 experimental currency in their Personal Account. They can use this endowment to purchase tokens. In the intra-group contest, there is a Faction Account common to the members of each faction, in which individuals can contribute tokens. The cost of contributing x tokens is $\frac{x^2}{100}$.[18] Each member decides independently how

[18] The choice variable for participants was the number of tokens, as opposed to the cost of contribution. We provided participants with a table in the instructions that showed the relationship by enumerating each contribution decision and its corresponding cost.

much of the 300 experimental currency to spend contributing tokens to the Faction Account.[19] Any amount not spent contributing tokens remains in the participant's Personal Account.

After participants have made their contribution decisions in the intra-group contest, the winning faction in each group is determined based on the relative number of tokens in each competing faction's account.[20] Participants observe (i) the total number of tokens contributed by their faction; (ii) the total number of tokens contributed by the competing faction in their group; (iii) the total number of tokens contributed by each faction in the *competing* group; and (iv) the outcome of the intra-group contest (which faction won or lost) for their own group as well as the competing group. This first stage interaction is the same for the Symmetric and Asymmetric treatment.

In the second stage, each participant is left with the remaining budget after deducting the cost of the first stage contributions. The second stage is similar to the first stage, except that members of each group now contribute tokens to a Group Account. Cost of contributing y tokens is $\frac{y^2}{100}$. Each member decides independently how much of her remaining budget to spend contributing tokens to the Group Account. Any amount not spent contributing tokens remains in the participant's Personal Account.

After participants make their contribution decisions, the winner of the second stage competition is determined based on the relative number of tokens in competing groups' accounts. Participants observe (i) the total number of tokens contributed by their group; (ii) the total number of tokens contributed by the competing group; and (iii) whether their group won or lost. We additionally elicited beliefs in each stage about contributions by in-group and out-group members for that stage.[21]

The rewards from the overall contest depend upon the outcomes of the two stages. To test for robustness, periods within a session varied in the value of v^H and v^L. We use two different value pairs - $\{v^H, v^L\}$ = {990, 330} and {750, 500}.[22] The computer randomly chose some periods to implement the first reward values and others with the second. Table 1 denotes the theoretical predictions assuming risk-neutrality. We structure our inquiry around the following hypotheses.

[19]Participants are told that they could purchase at most 173 tokens since they could not spend more than their endowment. Hence, the choice set for participants in the first stage was any integer between 0 and 173.

[20]The computer randomly picked a number r between 0 and 1. If $r \leq p_{i\mathbf{1}}$, faction **1** wins in group i. If $r > p_{i\mathbf{1}}$, faction **2** wins in group i.

[21]Beliefs were incentivized using the quadratic scoring-rule. Participants were paid for one randomly chosen belief elicitation.

[22]The prize values were set in such a way that expected payoff from the contests would be identical across the two reward structures, but the difference in contributions between the winning and losing factions would vary.

Hypothesis 1 *Individual contributions in the first stage will be higher for advantaged group members than for disadvantaged group members in the Asymmetric treatment. In the Symmetric treatment, first-stage contributions are the same across groups.*

- $x_{Aji} = x_{Bji}$ for the Symmetric treatment. ***(H1a)***
- $x_{Aji} > x_{Bji}$ for the Asymmetric treatment. ***(H1b)***

Hypothesis 2a *Individual contributions in the second stage will be higher for the winning faction than for the losing faction for both Symmetric and Asymmetric treatments.* ***(H2a)***

Hypothesis 2b *Conditional on the outcome of the first stage, individual contributions in the second stage will be identical across groups. In particular, this should also hold in the Asymmetric treatment across disadvantaged and advantaged group members.* ***(H2b)***

Participants were invited for one and half hours and played at most 20 decision periods of this two-stage contest, with a minimum of 10 periods.[23] One period was randomly chosen for payment. All experiments were computerized, using z-Tree (Fischbacher, 2007). The experiment was conducted at the Ohio State University. Participants were recruited from the undergraduate pool in the economics department. Each session lasted about 60 minutes and the average payment to a subject was $18.

TABLE 1. Parameters and Equilibrium Benchmarks

Treatment	Symmetric ($\alpha_A = \alpha_B = 1$)		Asymmetric ($\alpha_A = 2, \alpha_B = 1$)	
v^H	990	750	990	750
v^L	330	500	330	500
x_{Aji}	42	26	50	31
x_{Bji}	42	26	34	21
$y_{Awi} = y_{Bwi}$	68	53	64	50
$y_{Ali} = y_{Bli}$	23	35	21	33

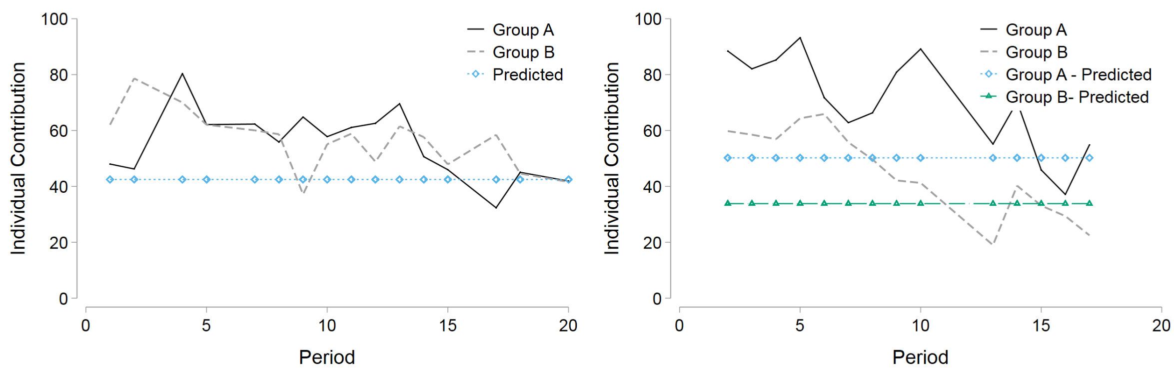
5. RESULTS

We have data from 152 participants from 3 sessions of the Symmetric and 5 sessions of the Asymmetric Treatment. Since we use a random-matching protocol, non-parametric tests are based on session averages of the relevant variables. For comparisons between groups (within

[23]On average there were more periods played in Symmetric sessions, as compared to the Asymmetric, because participants took longer to decide in the latter. In the Symmetric condition, 2 sessions played all 20 periods, while 1 session played 16 periods. In the Asymmetric condition, the median number of periods was 14, with maximum 18 and minimum 10. None of our results change qualitatively if we focus only on the first ten periods in both treatments.

a treatment), we have matched observations that allow us to use two-tailed Wilcoxon sign-rank test while for unmatched comparisons (between treatments) we use the two-tailed Mann-Whitney ranksum test. Since the results from the two reward structures are qualitatively similar, we report results from the case where $\{v^H, v^L\}$={990, 330} in the main text. Results for $\{v^H, v^L\}$={750, 500} can be found in Appendix 7.2.

5.1. *Stage 1 Contributions*



(a) Symmetric Treatment

(b) Asymmetric Treatment

FIGURE 3. Individual Contributions in the Intra-group Contest

We begin by focusing on individual contributions in the intra-group contest. Our main interest lies in understanding whether participants are forward-looking and internalize their group's relative position in the inter-group contest when making contribution decisions in the intra-group contest. Figure 3 depicts average individual contributions for every period by treatment. In the Symmetric treatment (Figure 3a), we observe no consistent difference in contributions across individuals in the two groups. Over all periods, the average individual contribution by members of Group A and Group B are 54.1 and 55.2 tokens, respectively (p-value=0.59, sign-rank test). In the Asymmetric treatment (Figure 3b), we observe individual contributions diverging between groups. Over all periods, the average individual contribution by members of Group A is 73.8 tokens while contribution by members of Group B is 50.35 tokens (p-value=0.04).[24] There is a tendency of contributions to decline over time in both treatments, but contributions by Group A members remain consistently higher. Hence, as predicted by ***H1b***, the intra-group contest is more intense in the group that is advantaged.

[24]Within each group, we find no difference between the contributions of the two factions, in line with theory. The ex-post probability of Faction **1** in each group winning the intra-group contest over all periods is 48% in the Symmetric treatment and 54% in the Asymmetric.

Table 2 presents a formal analysis of these observations. Because participants interacted repeatedly with session-wide random rematching, each subject cannot be treated as an independent observation. We use random-effects regressions with standard errors clustered at the session level to account for unobserved heterogeneity. We find the coefficient on *Group A* dummy to be positive and significant only in the Asymmetric condition, supporting the theoretical predictions.

TABLE 2. Stage 1 Individual Contributions

Dependent variable:	Individual Contribution	
	Sym	Asym
Group A	-1.01	26.9***
	(2.05)	(2.12)
Period	-1.01**	-1.4**
	(0.45)	(0.64)
Constant	66.3***	61.7***
	(6.18)	(10.6)
No. of Obs.	624	520
No. of Clusters	3	5

* p <0.10, ** p <0.05, *** p <0.01. Numbers in parenthesis are robust standard errors clustered at the session level. In the Asymmetric treatment, Group A denotes the advantaged group.

Result 1: *In the intra-group contests in the Asymmetric treatment, individuals in Group A contribute significantly more than individuals in Group B.*

Not only do individual contributions differ by groups in the Asymmetric treatment, but the frequency of zero contributions (or complete free-riding) is significantly higher in Group B than Group A. About 13% of decisions involve no contribution to the Faction Account in Group B, while Group A members always contribute a positive amount. Appendix Figure 11 depicts frequency of complete free-riding over periods for symmetric and asymmetric treatments, and both reward structures.

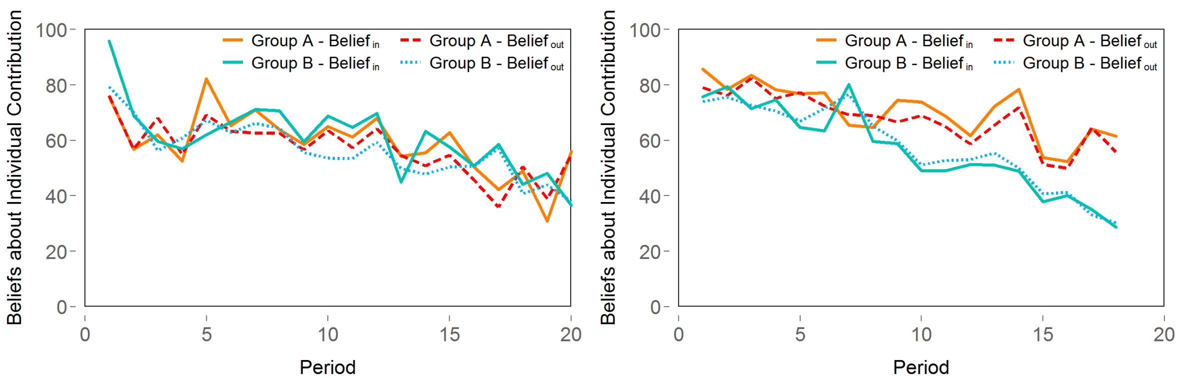
We also collect beliefs from individuals about the expected contributions of the other member in their faction ($Belief_{in}$), as well as the average individual contribution of the competing faction ($Belief_{out}$). Table 3 depicts how individuals' beliefs about own faction-member's contribution and the average contribution by the competing faction compares with each other and to their actual contribution. Given that the factions are homogeneous, one would expect individuals would predict their in-faction member to contribute similar to them. However, as reported in Column (1), only 20% of individuals state $Belief_{in}$ equal to their contribution. The

TABLE 3. Belief Comparisons

	(1) Own Contribution vs $Belief_{in}$	(2) Own Contribution vs $Belief_{out}$	(3) $Belief_{in}$ vs $Belief_{out}$
equal	20.2	13.4	15.2
more than	33.9	38.2	47.0
less than	45.9	48.4	37.8

Notes: Numbers denote percentage of observations. Data pooled across Symmetric and Asymmetric treatments.

majority of individuals ($\approx 46\%$) expect own contribution to be *less* than that of their own faction members. Hence, individuals display a tendency to free-ride on the contributions of their faction mates. This is also true of beliefs about contribution by the opponent faction (Column (2)). However, comparing $Belief_{in}$ to $Belief_{out}$ (Column (3)), we find that individuals are more optimistic about their faction mate contributing more than the average contribution of the other faction. In Table 9 in the Appendix, we show how accurate individuals' beliefs are.[25]



(a) Symmetric Treatment (b) Asymmetric Treatment

FIGURE 4. Beliefs in the intra-group contest

Notes: $Belief_{in}$ denotes subjects' beliefs about the contribution of the other member in their faction. $Belief_{out}$ denotes subjects' beliefs about the average individual contribution of the members in the opposing faction in their group. For example, *Group A-*$Belief_{out}$ denotes beliefs by a member of group A about the contribution of the opponent faction in group A.

Figure 4 depicts how beliefs evolve over the experiment. We find that beliefs about individual contribution decisions by own faction and opponent faction members are very close for both treatments. In the Asymmetric treatment, although members of Group A and Group B start with similar beliefs about the contributions within their group, these diverge over time. Hence, participants update their beliefs about others as the game evolves.

[25]It would be interesting to observe how individuals' contributions relate to the best-response to their beliefs. However, we did not elicit beliefs about future contributions to avoid moral hazard problems, so we are unable to make that comparison.

There is one subsidiary point to be made regarding how contribution levels compare with equilibrium. Studies on elimination contests with individuals find contestants over-invest relative to theoretical predictions in the first stage (Altmann et al. [2012]; Delfgaauw et al. [2015]; Parco et al. [2005]; Sheremeta [2010b]). While we find overcontribution over all periods, contributions have a significant downward trend and restricting analysis to observations in periods greater than ten finds no significant overcontribution.[26] This is contrary to previous papers on dynamic contests where overcontribution is reduced with repetition but does not disappear. Similarly, the experimental tests of sequential multi-battle contests, (Mago et al. [2013], Mago and Sheremeta [2017]) find overbidding in early (as well as later) battles.

One possible explanation why overcontribution is mitigated in our setting is the use of a convex cost structure. Chowdhury et al. [2014] finds that convex costs alleviate overbidding in individual one-stage contests. Indeed, Brookins et al. [2015] finds the bid-to-prediction ratio of two times in group contests employing a convex cost structure, as compared to four (Abbink et al. [2010]; Ahn et al. [2011]), if not five (Bhattacharya [2016]), using constant marginal cost. Additionally, Sheremeta [2010a] finds that disclosing information about the opponent's contribution after the first stage decreases first stage contributions in a two-stage individual contest. Since, in our experiment, participants receive full information about the opponent faction's as well as the opponent group's contributions after the first stage, this could mitigate overcontribution.[27] Hence, we find the qualitative as well as quantitative predictions of the intra-group contest hold in our data.

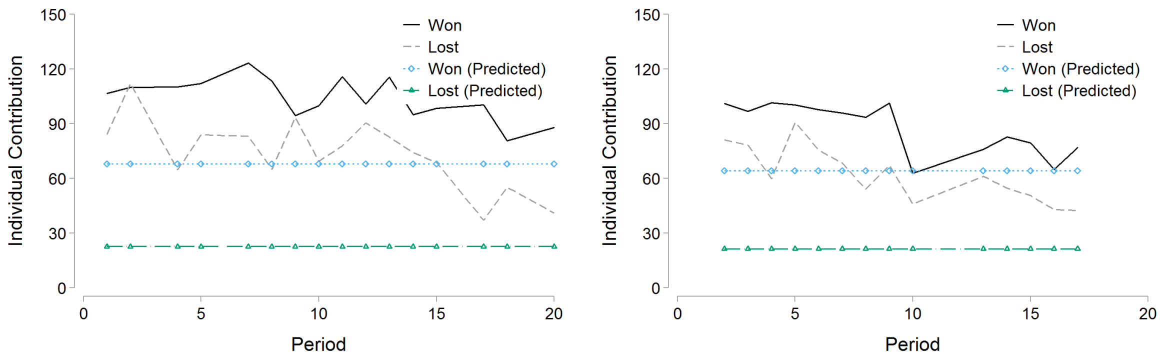
5.2. Stage 2 Contributions

In the inter-group contest, theory predicts unsurprisingly that participants condition their contributions on the outcome of the prior intra-group stage. Figure 5 depicts individual contributions in the inter-group contest conditional on whether the individual's faction won or lost in the intra-group contest, pooled across both groups. We find that contributions by first stage winners are always greater than by first stage losers. Consistent with Figure 5, regressions in Table 4 show that individuals in winning factions contribute significantly more than in losing factions.[28]

[26]We use a Wald test comparing the estimated constant in a linear regression to the equilibrium prediction for pooled groups in the Symmetric treatment (p-value=0.002) and each group separately in the Asymmetric treatment (p-values = 0.003; 0.02). For periods 10-20, the p-value is 0.15 for the Symmetric treatment and 0.15 and 0.43 for Group A and B respectively in the Asymmetric treatment. It is possible that insignificance is due to being underpowered since not all sessions lasted for the full 20 periods.

[27]Our observations are similar with reward value $\{750, 500\}$, where overcontribution starts at three times higher but quickly reduces.

[28]In the alternate reward structure $\{v^H, v^L\} = \{750, 500\}$, we observe similar qualitative difference in all groups barring Group B in the Symmetric treatment. see Appendix Table 10.



(a) Symmetric Treatment

(b) Asymmetric Treatment

FIGURE 5. Individual Contributions in the Inter-group Contest

TABLE 4. Stage 2 Individual Contributions

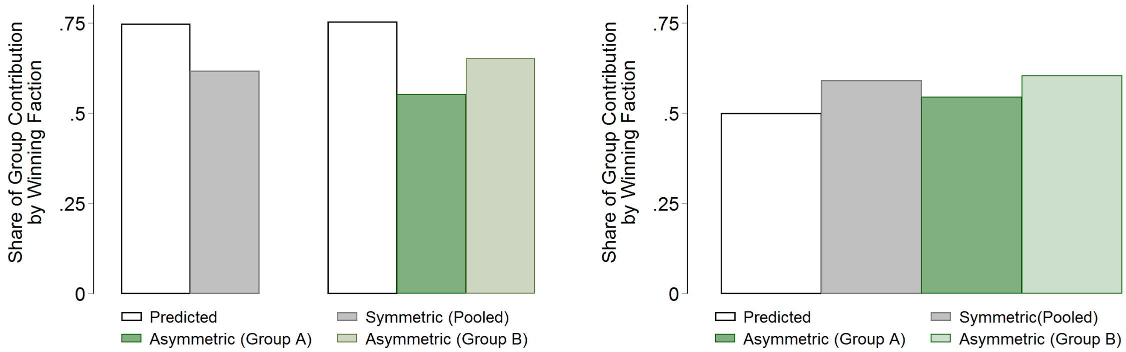
Dependent variable:	Individual Contribution			
	Symmetric		Asymmetric	
	Group A	Group B	Group A	Group B
Won$_{INTRA}$	27.38***	32.51***	11.78***	33.13***
	(3.02)	(3.72)	(3.98)	(2.22)
Period	-1.13	-2.42***	-1.03**	-2.58***
	(0.99)	(0.53)	(0.48)	(0.88)
Constant	85.67***	99.13***	85.59***	78.48***
	(8.29)	(0.58)	(5.95)	(9.18)
No. of Obs.	312	312	260	260
No. of Clusters	3	3	5	5

Notes: * p <0.10, ** p <0.05, *** p <0.01. Numbers in parenthesis are robust standard errors clustered at the session level. Won_{INTRA} is a dummy variable taking value 1 if the individual was in the winning faction in the intra-group contest. In the Asymmetric treatment (Column (3) and (4)), Group A and B denote the advantaged and disadvantaged groups respectively.

Result 2a: *In the inter-group contest, individuals in winning factions contribute significantly more than individuals in losing factions.*

Comparing individual contributions to equilibrium point predictions (cf. Figure 5), we observe significant overcontribution for both factions.[29] Although overcontribution reduces over time, it is not completely mitigated - restricting attention to periods greater than ten also shows significant overcontribution. It should be noted that in only 1.31% of the observations, individuals contributed so much in the first stage that they were constrained relative to equilibrium in the second stage. Our results do not change if we exclude these observations.

[29]For all treatments and factions, $p < 0.01$ (Wald test).



(a) Inter-group Contest (Second Stage) (b) Intra-group Contest (First Stage)

FIGURE 6. Average Share of Group Contribution by the Winning Faction

5.2.1. Coordinating Effort among Prior Rivals

The more interesting question is how do groups coordinate contributions among their winning and losing factions? Given our parameter values, theory predicts that winning faction's contribution should account for 75% of the group's total contribution in the inter-group contest. Figure 6(a) depicts the predicted and actual share of group contribution by the winning faction. Our results show the share to be around 54-60%, which is significantly lower than predictions. This implies that relative overcontribution by winners is less as compared to losers.[30] Following Sheremeta [2013], we compute for each individual, their *overbidding rate* ($\frac{actual-predicted}{predicted}$). Regressions confirm that, in all treatments, overbidding rate is significantly higher (p-value$<$0.001) for losers than winners of the intra-group contest. Hence we find that although both factions overcontribute, the losing factions shoulder a greater share of the group contribution than predicted by theory. Rather than being unwilling to cooperate with previous rivals, losers contribute *more* than what would be deemed strategic. In the following, we discuss two possible explanations that offer an insight into relative overcontribution by losers of the intra-group contest.

Relative Endowment Size: Sheremeta [2013] finds that the relative (to the prize value) size of endowment has a positive effect on the overbidding rate. Chowdhury and Moffatt [2017] and Baik et al. [2020] find a non-monotonic relationship between bids and and endowment. Overbidding increases as endowment is increased from a small level but declines for large levels of endowment. An individual's endowment in the second stage is the budget remaining after contributing in the first stage. Since factions are symmetric in the first stage, theory predicts they contribute the same and consequently, have the same endowment in the second

[30] While winners contribute 1.5 (1.4) times more, losers contribute 3.2 (3.1) times more as compared to theoretical benchmarks in the Symmetric (Asymmetric) treatment.

stage. However, the prize value for winners of the first stage is larger than for losers, generating a larger relative endowment for losers than winners. Comparing the empirical relative endowment size we find, losers have a relative endowment of 0.79 (0.76) compared to 0.25 (0.24) for winners in the Symmetric (Asymmetric) treatment. This asymmetry in the relative endowment size may lead to the observed asymmetry in overcontribution.

Non-monetary utility of Winning: A reason that has been proposed in the literature to explain overcontribution is a non-monetary benefit from winning, i.e., individuals are status-seeking, and over-exert effort. It is possible, that utility from winning a contest depends on the intermediate position of the contestants as the contest progresses. Berger and Pope [2011] show how being slightly behind in a competition during halftime can lead to greater effort exertion by the trailing team. Eriksson et al. [2009] finds that laggards almost never quit a tournament even when substantially behind. In our setting, individuals who lose the initial stage may value a win more than individuals who experienced a win, and hence be more willing to contribute. Our results go against the notion of psychological momentum (Cohen-Zada et al. [2017]) where winning may motivate contestants to exert higher effort, over and above strategic concerns.

To explore how factions contribute when they are symmetric, we look at their contributions in the first stage when the outcome of the contest is yet to be determined. Figure 6(b) displays the first stage contribution of the winning faction as a share of the first stage group total. Note that in this case, the factions are competing and not coordinating within the group as in the inter-group contest. Since in the intra-group contest, the factions are symmetric, the share of the winning faction should be 50%. Here, we find that winning factions are more competitive, contributing more than 50%. This is consistent with previous findings of elimination contests (Sheremeta [2010b]) where selection of competitive individuals can explain overcontribution in the second stage of an elimination contest.[31] However, surprisingly there is little difference between first and second stage factions' shares. Winning factions' contribution amounts to around 59% (57%) of the group total in the first stage while it amounts to 61% (60)% in the second stage for the Symmetric (Asymmetric) treatment. Hence, while theory predicts an increase of 25%, (from 50% to 75%) in the contributed shares by winning factions, we do not observe that in the data. This raises the question whether individuals respond strategically to a win in the intra-group contest, or our conclusion in Result 2a is driven by heterogeneity among factions' competitive predisposition leading more competitive factions to emerge as the winners.

[31] Individuals rarely play the unique pure-strategy equilibrium, and there is substantial variation in contribution decisions across subjects. This leads to more competitive individuals having a higher chance of winning the first stage and moving forward to the second.

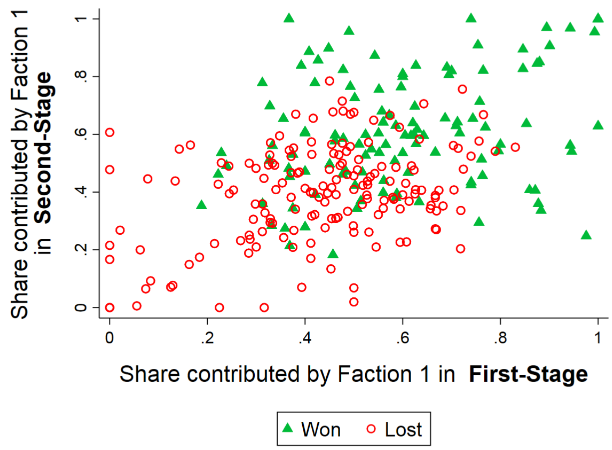


FIGURE 7. Faction 1's contribution to Group total

Figure 7 illustrates the relationship between contributed shares across the first and second stages by first stage outcomes. We observe a clear positive relationship between factions' contributions in the two stages. We also observe that higher shares in both stages correlate with being a winner in the first stage. However, in the vicinity of 0.5 where there is heterogeneity in outcomes, we do observe that for a given first stage share, winners are more likely to contribute a higher share in the second-stage than losers. Table 5 below shows this formally. We find that winning in the intra-group contest increases Faction 1's share of group contribution by around 18 percentage points in the Symmetric and 14 percentage point in the Asymmetric treatment. Hence, although heterogeneity among factions does play a role in determining outcomes, we find that individuals respond to the strategic incentives inherent in the contest.

We also elicit beliefs from participants about the total contribution of their group ($Belief_{in}$), as well as the total contribution of the competing group ($Belief_{out}$) in the second stage. We can look at how these beliefs compare between losers and winners within a group. Since both state beliefs about the same group (albeit given different prior outcomes) these beliefs should not differ between winners and losers. Table 6 depicts that in both treatments, winners and losers state similar beliefs about their group as well as the opponent group contribution. While winners do state higher beliefs about own group contribution than losers, these are not significantly different. Hence, although the *share* of contributions by losers within their group differs from equilibrium, losers harbor the same beliefs about total group contributions as winners.[32]

Theory also predicts that conditional on the outcome of the intra-group contest, individual contributions in the inter-group contest are identical across groups, irrespective of the group

[32]Figure 12 in the Appendix depicts beliefs over time by winners and losers of the intra-group contest.

TABLE 5. Stage 2 Contribution Share

Dependent variable:	Share of Faction 1's contribution to Group Account in Stage 2	
	Sym	Asym
Stage 1 share	0.299***	0.413***
	(0.02)	(0.08)
Won_{INTRA}	0.180**	0.139***
	(0.03)	(0.02)
Period	-0.001	-0.001
	(0.00)	(0.00)
Constant	0.267***	0.228***
	(0.02)	(0.05)
No. of Obs.	156	130
No. of Clusters	3	5

* p <0.10, ** p <0.05, *** p <0.01. Numbers in parenthesis are robust standard errors clustered at the session level. Observations only from Faction 1.

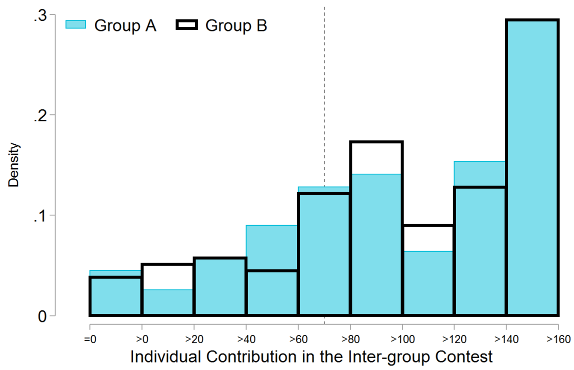
TABLE 6. Stage 2 Beliefs

		Winners	Losers	p-value
Symmetric	$Belief_{in}$	351.51	302.85	0.11
	$Belief_{out}$	339.90	325.91	0.28
Asymmetric	$Belief_{in}$	341.15	310.41	0.13
	$Belief_{out}$	324.13	324.51	0.89

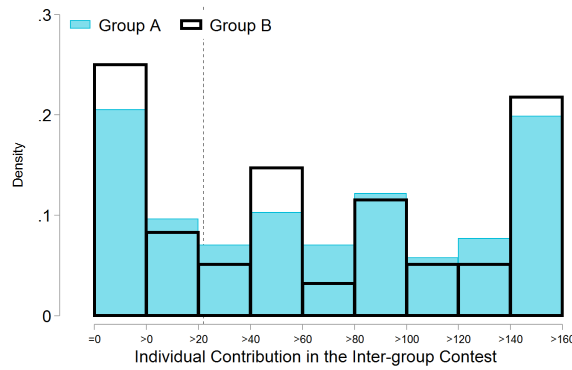
position (cf. Table 1). In order to observe whether this holds in our data, we plot the distribution of individual contributions in each treatment, conditional on the outcome of the intra-group contest (Figure 8). The top panel of Figure 8 depicts the Symmetric treatment. We find no significant difference across groups (p-value= 0.986 and 0.906 for winning and losing factions respectively, Ksmirnov test). The bottom panel (Asymmetric) shows some heterogeneity in contributions across groups. Importantly, comparing the losing factions across groups, there is a shift in contributions to the right for members of the advantaged groups.[33]

Consistent with Figure 8, a regression shows similar results. Table 7 shows that in the Symmetric treatment, winning and losing positions are the only significant predictors of individual contributions, while in the Asymmetric treatment contributions also differ by groups. For the Asymmetric treatment, the dummy variable *Group* A is positive and significant implying that for individuals who lost the intra-group contest (Won_{INTRA} = 0), those in the

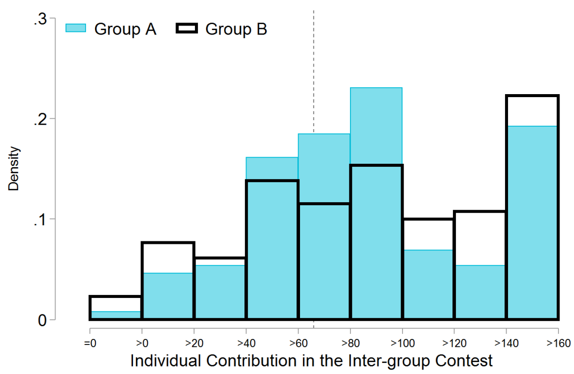
[33]Note that individuals' contributions being distributed so widely is inconsistent with a unique pure strategy Nash equilibrium.



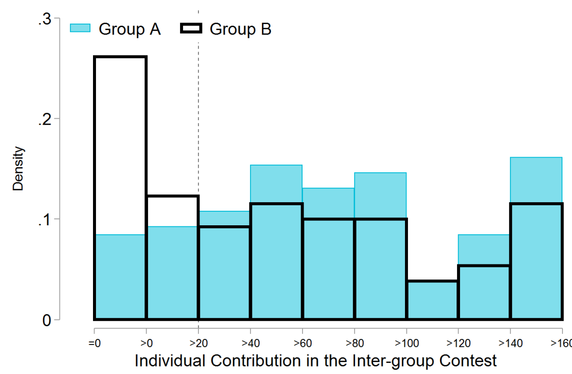
(a) Winning Faction (Symmetric)



(b) Losing faction (Symmetric)



(c) Winning Faction (Asymmetric)



(d) Losing faction (Asymmetric)

FIGURE 8. Distribution of Contribution across Groups

Notes: The top and bottom panels denote Symmetric and Asymmetric treatment, respectively. The vertical line represents the equilibrium individual contribution. In the Asymmetric treatment, Group A denotes the advantaged group. The first bar representes individual contributions equal to zero.

advantaged group contribute more than those in the disadvantaged group. The interaction between the group and winning position is negative implying that the difference in contributions across groups is significantly smaller for individuals in winning factions than in losing factions. Moreover, the coefficient on the interaction term is of a similar magnitude to that on *Group A*, implying the difference between groups is almost completely wiped out among individuals who win the intra-group stage.

A point that is worth noting is that the difference in contributions across groups that have lost is driven by contributions of the advantaged group being “too high" rather than those of the disadvantaged being “too low". Recall that individuals overcontribute on average. Hence, on average the disadvantaged group is closer to equilibrium predictions than the advantaged group. We find this difference across groups persists with repetition - restricting attention to periods 11-19, we still observe among the losing factions, those who belong to Group A contribute more than those who belong to Group B.

TABLE 7. Predicting Stage 2 Individual Contributions

Dependent variable:	Individual Contribution	
	Sym	Asym
Won_{INTRA}	29.9***	33.4***
	(3.0)	(2.5)
Group A	-1.7	21.2***
	(1.7)	(4.9)
Won_{INTRA} × Group A	-1.3	-23.1***
	(4.3)	(3.9)
Period	-1.8***	-1.8***
	(0.68)	(0.24)
Constant	94.4***	72.7***
	(5.0)	(5.7)
No. of Obs.	624	520
No. of Clusters	3	5

* p <0.10, ** p <0.05, *** p <0.01. Numbers in parenthesis are robust standard errors clustered at the session level. Won_{INTRA} is a dummy variable taking value 1 if the individual was in the winning faction.

It is possible that participants may apply similar strategies to both stages of the contest. Since individuals in the advantaged group contribute more in the intra-group contest, there may be a carryover effect that makes them contribute more in the inter-group contest too. However, since we only observe groups contributing differently for the losing faction, this is unlikely to be the reason.

Result 2b: *In the Asymmetric treatment, individuals in losing factions of advantaged groups contribute significantly more than individuals in losing factions of disadvantaged groups.*

6. DISCUSSION

Many sequential contests are characterized by opponents from a prior stage becoming allies at a later stage. In order to understand the dynamics of this kind of contest, we develop in this paper, a two-contest model where, in the first stage individuals compete within their group, while in the second stage, they compete collectively across groups. To the best of our knowledge, this is the first paper that studies such an interaction.

The incentives for cooperation within a group arises in our model as rewards accrue only to the group that wins the second stage. The value of this reward is determined by the outcome of the first stage, with members who win the first stage receiving a greater value than members who lose. In line with previous studies that introduce such a 'win advantage' in dynamic contests, we show that individuals winning the intra-group contest, who stand to gain more from their group's victory, dominate their group's efforts towards winning the inter-group contest. However, in our context, this win advantage may not hold literally and translate to a real advantage as early winners can receive a lower payoff than losers. The implication of this is pronounced in the first stage, where incentives to contribute may be absent.

We also show how an exogenous advantage for a group, imposed through a biased group contest success function affects effort in the first stage and not the second stage. Our experimental findings lend support to this prediction. We find participants within advantaged groups internalize their group's second stage advantage in their first stage choices and indeed the intra-group contest in advantaged groups is more intense. Our experimental results also inform on how the group contribution is split among individuals from winning and losing factions. We find that losing faction members overcontribute to a significantly greater degree than winning faction members within a group i.e., the losing members bear a greater burden of the group contribution than deemed strategic.

The theory we develop is very general and has many applications like faculty recruiting, partisan support in US elections, R&D project competition in firms. For example, we show why factions may willingly sacrifice competing within their groups when there is small difference in policy positions. Additionally, we show that a future advantage could increase conflict expenditure in a prior stage. Finally, we show that a prior win has behavioral implications for how groups coordinate effort among themselves. Our model is simple and can be extended in many directions. We focus on situations where contestants do not derive any benefit from the rival group winning. One possibility for preferences is that the contestants prefer a faction in the rival group winning to the other faction in their group.[34] We also abstract away from the group size discussion by assuming equal sized groups. Exploring these would be interesting avenues for future research. In addition, future research can extend our work by focusing on different group contest success functions (weakest link (Lee [2012]), best-shot (Chowdhury et al. [2013]), etc.).

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[34]This would significantly weaken the group identity. An example of such transfer of support across party lines has been observed in the 2016 election where many Ted Cruz supporters voted for Hillary Clinton.

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7. Appendix

7.1. Proofs

Proof of Proposition 1

(i) In the second stage, if i is in the winning faction, her expected payoff is

$$\pi_{gWi} = \frac{\alpha_g Y_g}{\alpha_g Y_g + \alpha_{g'} Y_{g'}} v^H + \omega - C(y_{gWi}) - C(x_{gfi}).$$

The first-order condition with respect to y_{gWi} yields

$$\frac{v^H \alpha_g \alpha_{g'} Y_{g'}}{(\alpha_g Y_g + \alpha_{g'} Y_{g'})^2} - C_y(y_{gWi}) = 0. \tag{7}$$

The strict concavity of π_{gWi} with respect to y_{gWi} implies *uniqueness* of the stationary point or the optimum, if a stationary point exists. To prove *existence* of an optimal y^*_{gWi}, consider the left side of (7). Note that $Y_{g'} = 0$ cannot be the case in equilibrium because $C_y(0) = 0$ holds and any member of group g' will see a strict marginal increase in probability of winning and thereby his expected prize if he increases his contribution when his contribution (and contribution of all other members of g') equals 0. So $Y_{g'} > 0$ holds. At $y_{gWi} = 0$, the left side of (7) is strictly positive. As y_{gWi} increases, the left side of (7) strictly decreases because $\frac{v^H \alpha_A \alpha_B Y_{g'}}{(\alpha_A Y_A + \alpha_B Y_B)^2}$ strictly decreases and, by strict convexity, $C_y(y_{gWi})$ strictly increases. Thus, allowing for unconstrained ω, there exists a y^*_{gWi} such that (7) holds. Rearranging (7) yields:

$$y^*_{gWi} = C_y^{-1}\left[\frac{v^H \alpha_g \alpha_{g'} Y^*_{g'}}{(\alpha_g Y^*_g + \alpha_{g'} Y^*_{g'})^2}\right].$$

To prove $y^*_{gWi} = y^*_{gWj}$ where $i, j \in g$ (symmetry of y^* within a faction), note that for any $j \in gW$ (the winning faction of group g) s.t. $j \neq i$, the right side of (4) is the same, so $y^*_{gWi} = y^*_{gWj}$ must hold.

Uniqueness, existence and symmetry hold by a similar argument for y^*_{gLi}.

(ii) Symmetry across individuals within each faction yields

$$Y^*_g = n[C_y^{-1}(\frac{v^H\alpha_g\alpha_{g'}Y^*_{g'}}{(\alpha_g Y^*_g+\alpha_{g'}Y^*_{g'})^2}) + C_y^{-1}(\frac{v^L\alpha_g\alpha_{g'}Y^*_{g'}}{(\alpha_g Y^*_g+\alpha_{g'}Y^*_{g'})^2})]. \tag{8}$$

By way of contradiction, suppose $Y^*_A > Y^*_B$ holds. Then, by (8),

$$C_y^{-1}(\tfrac{v^H\alpha_A\alpha_B Y^*_B}{(\alpha_A Y^*_A+\alpha_B Y^*_B)^2}) + C_y^{-1}(\tfrac{v^L\alpha_A\alpha_B Y^*_B}{(\alpha_A X^*_A+\alpha_B X^*_B)^2}) > C_y^{-1}(\tfrac{v^H\alpha_A\alpha_B Y^*_A}{(\alpha_A Y^*_A+\alpha_B Y^*_B)^2}) + C_y^{-1}(\tfrac{v^L\alpha_A\alpha_B Y^*_A}{(\alpha_A Y^*_A+\alpha_B Y^*_B)^2}), \tag{9}$$

must hold. By the inverse function theorem, the derivative of $C_y^{-1}(y)$ equals $\frac{1}{C_{yy}(C_y^{-1}(y))}$, which is strictly positive given strict convexity of the cost function. Since $Y^*_A > Y^*_B$, so $\frac{dC_y^{-1}(y)}{dy} > 0$ implies

$$C_y^{-1}(\frac{v^H\alpha_A\alpha_B Y^*_A}{(\alpha_A Y^*_A+\alpha_B Y^*_B)^2}) > C_y^{-1}(\frac{v^H\alpha_A\alpha_B Y^*_B}{(\alpha_A Y^*_A+\alpha_B Y^*_B)^2}), \text{ and}$$
$$C_y^{-1}(\frac{v^L\alpha_A\alpha_B Y^*_A}{(\alpha_A Y^*_A+\alpha_B Y^*_B)^2}) > C_y^{-1}(\frac{v^L\alpha_A\alpha_B Y^*_B}{(\alpha_A Y^*_A+\alpha_B Y^*_B)^2}),$$

must hold. This contradicts (9).

(iii) and **(iv)** Since C_y^{-1} is strictly increasing, replacing $Y^*_A = Y^*_B = Y$ in (4) and (5) implies $y^*_{AWi} = y^*_{BWj}$, $y^*_{ALi} = y^*_{BLj}$, and $y^*_{gWi} > y^*_{gLi}$ hold for all $i \in A$, $j \in B$, and $g = A, B$. □

Proof of Proposition 2

(i) and **(ii)** The expected payoff of each individual is

$$\begin{aligned}\pi_{gfi} = \omega - C(x_{gfi}) &+ \tfrac{X_{gf'}}{X_{gf}+X_{gf'}}[\tfrac{\alpha_g Y_g}{\alpha_g Y_g+\alpha_{g'}Y_{g'}}v^L - C(y^*_{gLi})] \\ &+ \tfrac{X_{gf}}{X_{gf}+X_{gf'}}[\tfrac{\alpha_g Y_g}{\alpha_g Y_g+\alpha_{g'}Y_{g'}}v^H - C(y^*_{gWi})].\end{aligned}$$

Given y^*_{gWi}, y^*_{gLi}, and $Y^*_g = Y^*_{g'}$, the expected payoff in the first-stage takes the form

$$\pi_{gfi} = \omega - C(x_{gfi}) + \frac{X_{gf'}}{X_{gf}+X_{gf'}}[\frac{\alpha_g}{\alpha_g+\alpha_{g'}}v^L - C(y^*_{gLi})] + \frac{X_{gf}}{X_{gf}+X_{gf'}}[\frac{\alpha_g}{\alpha_g+\alpha_{g'}}v^H - C(y^*_{gWi})].$$

Rearranging terms yields:

$$\pi_{gfi} = \frac{X_{gf}}{X_{gf}+X_{gf'}}[\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi})] - \frac{X_{gf'}}{X_{gf}+X_{gf'}}C(y^*_{gLi}) + \frac{\alpha_g}{\alpha_g+\alpha_{g'}}v^L + \omega_i - C(x_{gfi}).$$

The first order condition of π_{gfi} with respect to x_{gfi} yields

$$0 = \frac{X_{gf'}}{(X_{gf}+X_{gf'})^2}[\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})] - C_x(x_{gfi}). \tag{10}$$

Clearly, if $\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi}) \leq 0$, holds then $x^*_{gfi} = 0$ is optimum. Next, suppose, $\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi}) > 0$ holds. So the second-order condition is satisfied because a derivative of the right side of (10) with respect to x_{gfi} yields

$$-2\frac{X_{gf'}}{(X_{gf}+X_{gf'})^3}[\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})] - C_{xx}(x_{gfi}),$$

which is strictly negative. Thus, the x^*_{gfi} that solves (10) must be unique if such a x^*_{gfi} exists. Using $C_x(0) = 0$, the arguments for $Y_{g'} > 0$ can be repeated to show that $X_{gf'} > 0$ must hold. So, at $x_{gfi} = 0$, the right side of (10) is strictly positive because $C_x(0) = 0$ holds. Further, as x_{gfi} increases, right side of (10) strictly decreases because the first term on the right side of (10) strictly decreases (since $[\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})] > 0$ holds) while $C_x(x_{gfi})$ strictly increases (due to strict convexity). Thus, allowing for "large enough" ω, there exists a x^*_{gfi} such that (10) holds.

By (10) we have

$$x^*_{gfi} = C_x^{-1}[\frac{X^*_{gf'}}{(X^*_{gf}+X^*_{gf'})^2}\{\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})\}]. \tag{11}$$

Symmetry of x^* within each faction again follows because for any $j \neq i$, such that $j \in g_f$ (i.e., j is also in faction f of group g), the right side of (11) is the same.

(iii) Let $X^*_{g1} > X^*_{g2}$ hold. Then (11) implies

$$\begin{aligned} C_x^{-1}[\tfrac{X^*_{g2}}{(X^*_{g1}+X^*_{g2})^2}\{\tfrac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})\}] > \\ C_x^{-1}[\tfrac{X^*_{g1}}{(X^*_{g1}+X^*_{g2})^2}\{\tfrac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})\}]. \end{aligned} \tag{12}$$

The implicit function theorem and strict convexity of $C(.)$ imply that C_x^{-1} is strictly increasing. So $X^*_{g1} > X^*_{g2}$ implies that the inequality in (12) must be reversed, a contradiction.

(iv) Let $\alpha_g > \alpha_{g'}$, $x^*_{gfi} > 0$ and $X_g \leq X_{g'}$ hold. Using $X^*_{g1} = X^*_{g2} = X_g$ and symmetry within each faction in (11), we have,

$$X_g = nC_x^{-1}[\frac{1}{4X_g}\{\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})\}]. \tag{13}$$

Given $\alpha_g > \alpha_{g'}$ and our assumption of $X_g \leq X_{g'}$, the following hold: (a) $\frac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} > \frac{\alpha_{g'}(v^H-v^L)}{\alpha_g+\alpha_{g'}}$; (b) $\frac{1}{4X_g} \geq \frac{1}{4X_{g'}}$. The derivative of $C_x^{-1}(.)$ is strictly positive. So (a) and (b) imply

$$\begin{aligned} X_g = nC_x^{-1}[\tfrac{1}{4X_g}\{\tfrac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})\}] > \\ nC_x^{-1}[\tfrac{1}{4X_{g'}}\{\tfrac{\alpha_g(v^H-v^L)}{\alpha_g+\alpha_{g'}} - C(y^*_{gWi}) + C(y^*_{gLi})\}] = X_{g'}, \end{aligned}$$

that is, if $\alpha_g > \alpha_{g'}$ holds, then $X_g \leq X_{g'}$ yields a contradiction. $\square$

Proof of Proposition 3

(i) Let the function C_y^{-1} be denoted as h, which is a strictly monotonic function since C is strictly convex. From Proposition 1 we have:

$$y^*_{gWi} = h[\frac{v^H \alpha_g \alpha_{g'}}{(\alpha_g + \alpha_{g'})^2 Y^*}]; \text{ and } y^*_{gLi} = h[\frac{v^L \alpha_g \alpha_{g'}}{(\alpha_g + \alpha_{g'})^2 Y^*}].$$

The partial derivative of y^*_{gWi} with respect to v^L yields

$$\frac{\partial y^*_{gWi}}{\partial v^L} = -h'[\frac{v^L \alpha_g \alpha_{g'}}{(\alpha_g + \alpha_{g'})^2 Y^*}]\frac{v^L \alpha_g \alpha_{g'} n}{(\alpha_g + \alpha_{g'})^2 (Y^*)^2}(\frac{\partial y^*_W}{\partial v^L} + \frac{\partial y^*_L}{\partial v^L})$$

Let $h'[\frac{v^L \alpha_A \alpha_B}{(\alpha_A + \alpha_B)^2 Y^*}]\frac{v^L \alpha_A \alpha_B n}{(\alpha_A + \alpha_B)^2 (Y^*)^2} = K$. Note that $K > 0$ holds since $h'(.) > 0$ holds. So, we have

$$\frac{\partial y^*_W}{\partial v^L} = -\frac{K}{(1+K)}\frac{\partial y^*_L}{\partial v^L}. \tag{14}$$

We now argue that $\frac{\partial y^*_L}{\partial v^L} > 0$ holds. Suppose not; that is, let $\frac{\partial y^*_L}{\partial v^L} \leq 0$ hold, then Y^* must be strictly increasing in v^L since h is strictly increasing. Note that if $\frac{\partial y^*_L}{\partial v^L} \leq 0$ holds, then (14) implies $\frac{\partial y^*_W}{\partial v^L} \geq 0$ and $|\frac{\partial y^*_L}{\partial v^L}| \geq |\frac{\partial y^*_W}{\partial v^L}|$ hold. Since $Y^* = n(y^*_W + y^*_L)$ holds, Y^* must be non-increasing in v^L if $\frac{\partial y^*_L}{\partial v^L} \leq 0$ holds; a contradiction.

Since $\frac{\partial y^*_L}{\partial v^L} > 0$ holds and (14) implies that $\frac{\partial y^*_W}{\partial v^L}$ and $\frac{\partial y^*_L}{\partial v^L}$ have opposite signs, it follows that $\frac{\partial y^*_W}{\partial v^L} < 0$ holds. Further, (14) implies $|\frac{\partial y^*_L}{\partial v^L}| > |\frac{\partial y^*_W}{\partial v^L}|$, so Y^*, which is equal to $n(y^*_W + y^*_L)$, is also strictly increasing in v^L. □

Proposition 4. *If v^H is the same for both groups, but v^L for group g is greater than for group g', i.e., if $v^L(g) > v^L(g')$ holds, then: (a) $y^*_{gLi} > y^*_{g'Li}$; (b) $Y^*_g > Y^*_g$; and (c) $y^*_{gWi} < y^*_{g'Wi}$ hold.*

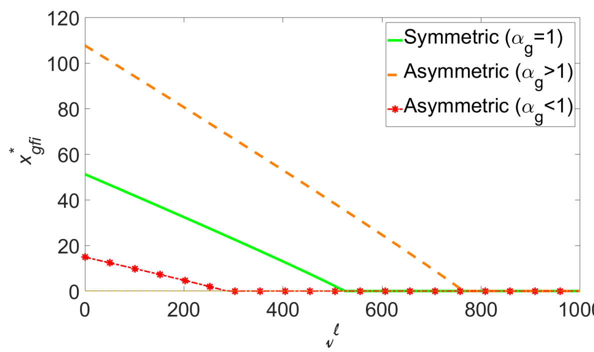
Proof. From the first order conditions for y^*_g and $y^*_{g'}$ we have:

$$h(\frac{v^H \alpha_g \alpha_{g'} Y^*_{g'}}{(\alpha_g Y^*_g + \alpha_{g'} Y^*_{g'})^2}) = y^*_{gWi} \text{ and } h(\frac{v^H \alpha_g \alpha_{g'} Y^*_g}{(\alpha_g Y^*_g + \alpha_{g'} Y^*_{g'})^2}) = y^*_{g'Wi},$$

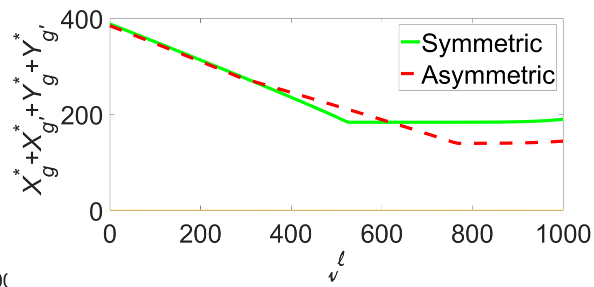
$$h(\frac{v^L(g) \alpha_g \alpha_{g'} Y^*_{g'}}{(\alpha_g Y^*_g + \alpha_{g'} Y^*_{g'})^2}) = y^*_{gLi} \text{ and } h(\frac{v^L(g') \alpha_g \alpha_{g'} Y^*_g}{(\alpha_g Y^*_g + \alpha_{g'} Y^*_{g'})^2}) = y^*_{g'Li}.$$

Since $v^L(g) > v^L(g')$, assuming $Y^*_{g'} \geq Y^*_g$ yields a contradiction. To see this, note that $Y^*_{g'} \geq Y^*_g$ implies $y^*_{gWi} \geq y^*_{g'Wi}$ and $y^*_{gLi} > y^*_{g'Li}$ because $h = C_y^{-1}$ is strictly increasing and $v^L(g) > v^L(g')$ holds. But $y^*_{gWi} \geq y^*_{g'Wi}$ and $y^*_{gLi} > y^*_{g'Li}$ together imply $Y^*_{g'} < Y^*_g$, a contradiction. So, we must have $Y^*_{g'} < Y^*_g$. Since h is strictly increasing, it is straightforward to see that $y^*_{gWi} < y^*_{g'Wi}$ and hence (given $Y^*_{g'} < Y^*_g$) $y^*_{gLi} > y^*_{g'Li}$ hold. □

7.2. Additional Tables and Figures



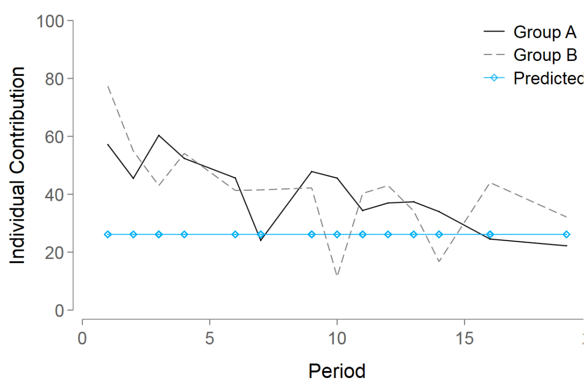
(a) x_{gfi}



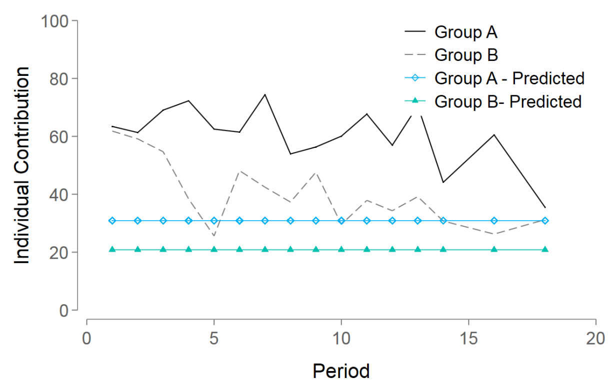
(b) Total Contribution

FIGURE 9. Total Contributions in the Intra-group Contest across Group Position

Notes: $n = 1$, *and* $v^H = 1000$, *Cost function :* $x_{gfi}^{1.05}$



(a) Symmetric Treatment



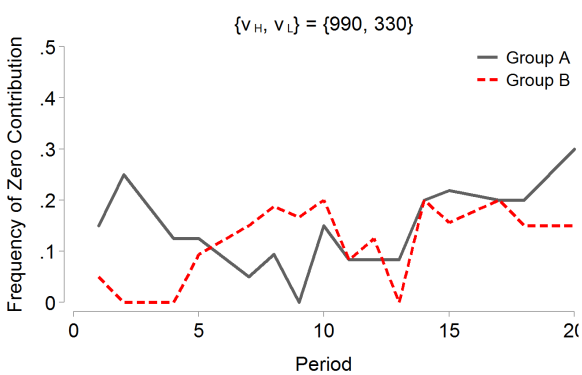
(b) Asymmetric Treatment

FIGURE 10. Individual Contributions in the Intra-group contest ($\{v^H, v^L\} = \{750, 500\}$)

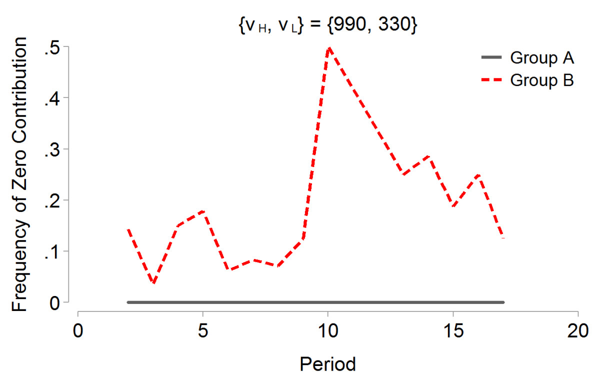
TABLE 8. Stage 1 Individual Contributions (Reward: $\{v^H, v^L\} = \{750, 500\}$)

Dependent variable:	Individual Contribution	
	Sym	Asym
Group A	2.9**	19.05***
	(1.05)	(3.2)
Period	-1.53**	-1.17**
	(0.17)	(0.44)
Constant	55.07***	52.77***
	(3.51)	(6.39)
No. of Obs.	560	744
No. of Clusters	3	5

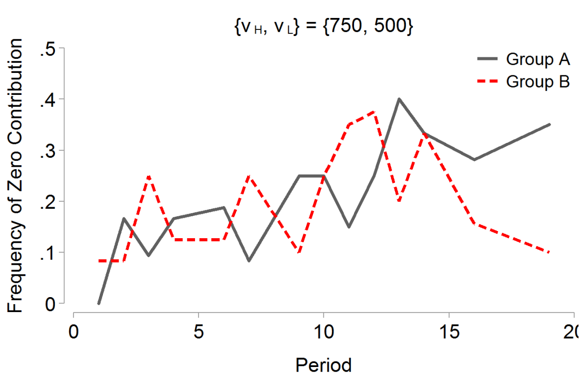
* p <0.10, ** p <0.05, *** p <0.01. Numbers in parenthesis are robust standard errors clustered at the session level. In the Asymmetric treatment, Group A denotes the advantaged group.



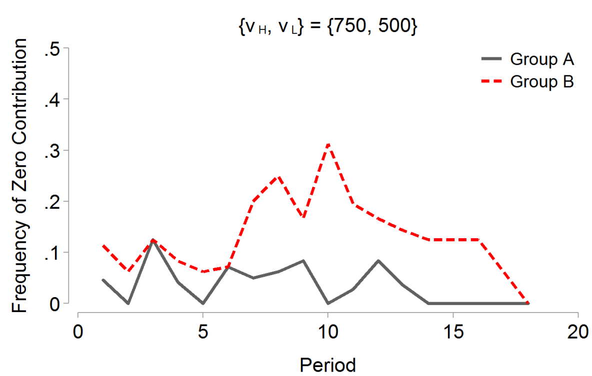
(a) Symmetric Treatment



(b) Asymmetric Treatment



(c) Symmetric Treatment



(d) Asymmetric Treatment

FIGURE 11. Frequency of Zero Contributions in the Intra-group Contest

TABLE 9. Mean Absolute Error in Belief Estimation in the Intra-Group Contest

	Group	$Belief_{in}$	$Belief_{out}$
Symmetric	Both	47.7	33.8
Asymmetric	Group A	40.5	31.6
	Group B	44.8	37.3

TABLE 10. Stage 2 Individual Contributions (Reward: $\{v^H, v^L\} = \{750, 500\}$)

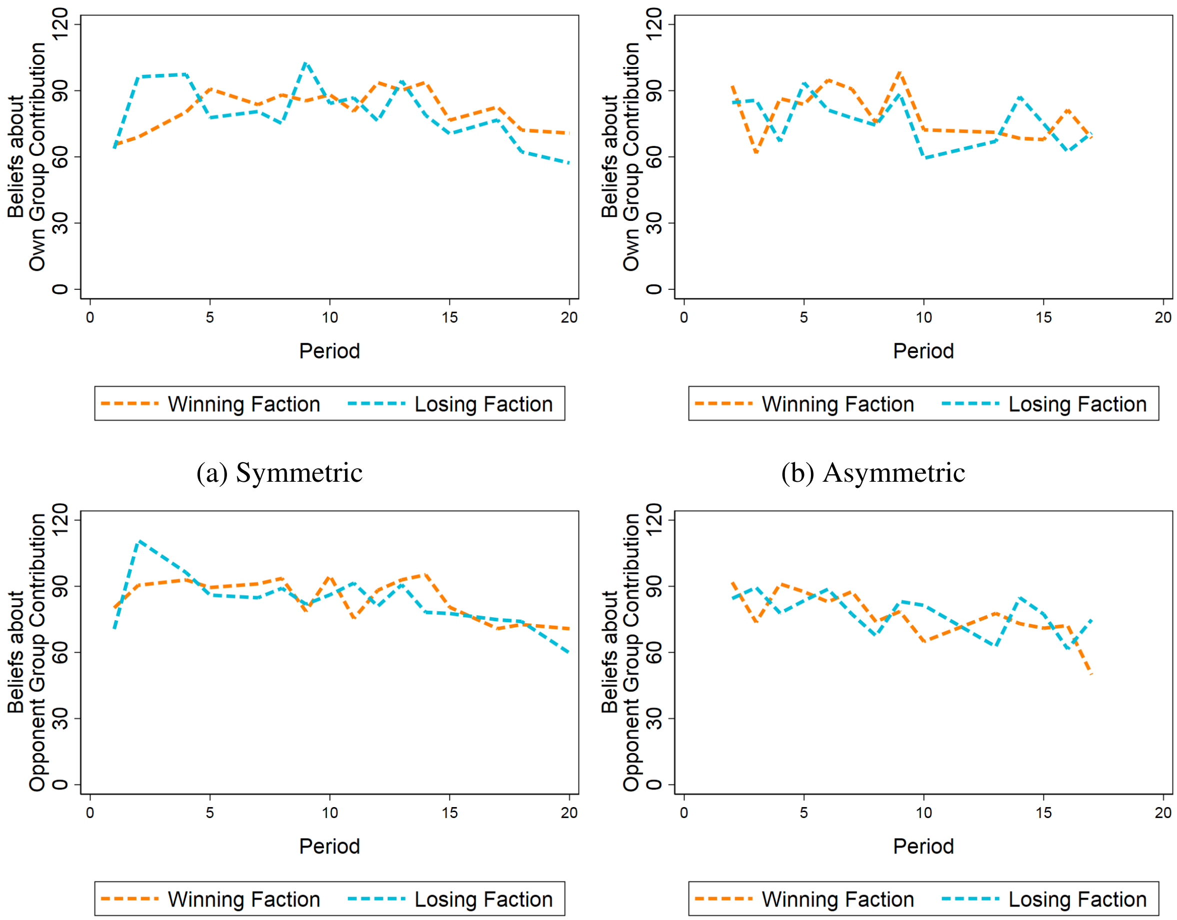
Dependent variable:	Individual Contribution			
	Symmetric		Asymmetric	
	Group A	Group B	Group A	Group B
Won$_{INTRA}$	7.538***	3.504	5.160***	12.311***
	(2.22)	(7.45)	(1.68)	(3.34)
Period	-1.757***	-2.430***	-0.713	-1.760***
	(0.34)	(0.30)	(0.44)	(0.52)
Constant	108.607***	108.467***	93.946***	83.266***
	(4.24)	(5.33)	(8.04)	(5.22)
No. of Obs.	280	280	372	372
No. of Clusters	3	3	5	5

Notes: * p <0.10, ** p <0.05, *** p <0.01. Numbers in parenthesis are robust standard errors clustered at the session level. Won_{INTRA} is a dummy variable taking value 1 if the individual was in the winning faction in the intra-group contest. In the Asymmetric treatment (Column (3) and (4)), Group A and B denote the advantaged and disadvantaged groups respectively.

TABLE 11. Predicting Stage 2 Individual Contributions (Reward: $\{v^H, v^L\} = \{750, 500\}$)

Dependent variable:	Individual Contribution	
	Sym	Asym
Won$_{INTRA}$	5.040	11.814***
	(5.90)	(3.61)
Group A	5.889	20.458***
	(4.57)	(4.09)
Won$_{INTRA}$ X Group A	1.406	-8.910***
	(4.39)	(3.00)
Period	-2.087***	-1.264***
	(0.25)	(0.47)
Constant	105.073***	79.633***
	(2.87)	(5.12)
No. of Obs.	560	744
No. of Clusters	3	5

* p <0.10, ** p <0.05, *** p <0.01. Numbers in parenthesis are robust standard errors clustered at the session level. Won_{INTRA} is a dummy variable taking value 1 if the individual was in the winning faction.



(a) Symmetric

(b) Asymmetric

(c) Symmetric

(d) Asymmetric

FIGURE 12. Beliefs in the Inter-group Contest