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The Perks of Being in the Smaller Team: Incentives in Overlapping Contests

Abstract

We investigate overlapping contests in multi-divisional organizations in which an individual's effort simultaneously determines the outcome of several contests on different hierarchical levels. We show that individuals in smaller units are advantaged in the grand (organization-wide) contest for two reasons: First, the incentive to free-ride is smaller in inter-divisional contests. Second, competition in the intra-divisional contest is less fierce. Both effects induce a higher marginal utility of effort provision. We test the model in a laboratory experiment and confirm its main predictions. Our results have important consequences for the provision of incentives in organizations and the design of sports competitions.

JEL-Codes: C720, C920, D720.

Keywords: contest, rent-seeking, hierarchy, teams, experiment.

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1 Introduction

Contests are situations in which individuals compete for a prize by spending non-refundable effort which increases the likelihood of winning but does not guarantee victory (see e.g. Konrad, 2009). In this sense, many everyday situations may be described as a contest. Indeed, individuals are usually involved in several contests at once. Some of these contests may overlap meaning that they take place on different levels of a given hierarchy and the same effort is relevant (to some extent) for the outcome of each of these contests.

Take sports as a classical example. In the Olympic games, in addition to individual victories, media attention is frequently drawn to the medal table which counts the success of the different nations. Similarly, the *Tour de France* honors the best team in addition to the best cyclists. In these situations, athletes simultaneously face a grand contest and an inter-team contest between teams partitioning the field. In addition, an athlete's success relative to the other athletes of the same nation may determine her chances of receiving funding in the next season or taking part in a subsequent competition.[1]

Similar situations arise at the workplace where workers may not only struggle to be promoted within the organization, but may simultaneously fight for relative standing within their own division or standing and funding of the division within the entire organization. It is then not always possible to distinguish tasks most relevant for the organization-wide contest from tasks more relevant for the inter- or intra-divisional contests.

In this paper, we investigate overlapping contests in which an individual's effort simultaneously determines the outcome of several contests taking place at different levels of a given hierarchy. We show that individuals in larger divisions have a disadvantage in the organization-wide contest. This result is driven by two well-known effects: First, larger divisions induce larger incentives to free-ride in inter-divisional contests (see e.g. Konrad, 2009). Second, the intra-divisional contest is fiercer the larger the division. Both effects lower the marginal utility of effort provision.

Though these predictions follow straightforwardly from contest theory, their behavioral relevance is not clear. First, overbidding is increasing in the group size in intra-group contests (see Sheremeta, 2013). Second, experiments on contests between groups (or *teams*) show that members of larger groups overbid more relative to Nash equilibrium than members of smaller groups (Sheremeta, 2018). Therefore, the "group size paradox" according to which smaller groups may be more likely to win in inter-group contests due to smaller free-riding problems, often does not materialize in the laboratory. One explanation is the salience of *group identity* in connection with *parochial altruism* which makes subject care about the incentives of their group (see e.g Abbink et al., 2012, Chowdhury et al., 2016). Whether these results translate into overlapping contests is an open question.

[1]For example, in the 2018 Olympic winter games German luger Felix Loch by losing the gold medal in the final run, also lost the chance to compete in the subsequent team contest.

For example, introducing an additional contest in which each individual fights for herself regardless of group membership may dilute the salience of group identity and reemphasize an individual's personal identity.[2] As a consequence, individual incentives may regain importance.

To investigate the behavioral relevance of the model, we conduct a laboratory experiment. In our experimental setup, subjects are assigned to groups of six players and divided in two teams of two and four players, respectively. In each round each subject simultaneously competes in a group-wide (grand) Tullock contest and either an inter-team contest with winnings divided equally among the members of the winning team, or an intra-team contest. While groups are randomly formed in each repetition, subjects are consistently assigned either to the small or to the large team. Given the prizes we choose for the contests, our model predicts that subjects in the smaller team invest twice (1.25 times) as much as subjects in the larger team and are thus twice (1.25 times) as likely to win, if they simultaneously face a grand contest and an inter-team (intra-team) contest. Though we find, like many other studies, that subjects substantially overinvest, members of the small team invest 42% (23%) more than members of the large team, if simultaneously facing the grand and the inter-team (intra-team) contest. As a consequence, subjects assigned to the small team achieve substantially higher earnings in both treatments.

Our results have important implications for contest design: First, maintaining similar chances in the organization-wide contest requires the prize in the intra-divisional contest to rise in the size of the division, and larger divisions may be forced to spend more per capita than smaller divisions. Second, a contest designer interested in effort provision should devote all resources to the organization-wide contest. Third, adding an organization-wide contest to a contest between teams of different sizes will equalize the chances of the two teams and may serve as a conflict resolution mechanism.

The paper relates to a wide and growing theoretical literature starting with Tullock (1980). Nitzan (1991) was the first to study contests between teams and highlight the free-riding problem. Several other papers have extended this literature by investigating the combination of an inter-team contest with the corresponding intra-team contest which ensues in the winning team over the realized winnings. Most papers study the sequential version of this problem (see e.g. Katz and Tokatlidu, 1996, Wärneryd, 1998, Inderst et al., 2007). Recently, Münster (2007) and Münster and Staal (2012), among others, have started investigating the simultaneous inter- and intra-team contest for a given prize where subjects choose how to distribute their effort between the inter- and the intra-team contest and a production task. In contrast, the focus of this paper is on simultaneous contests with separate prizes whose outcomes are determined by a single effort choice for

[2]See e.g. Oakes and Turner (1986) who show that in a given situation only one identity is psychologically real.

each player.[3] Moreover, we focus on the combination of a grand contest with inter- and intra-team contests.

The paper also contributes to a large and growing experimental literature on contests between individuals (see Dechenaux et al., 2015, Sheremeta, 2013, for recent surveys) and between teams (see Sheremeta, 2018). In particular, Ke et al. (2013) and Ke et al. (2015) study the interaction of a team contest and a subsequent individual contest within the winning team. To the best of our knowledge, no experimental study has yet tested overlapping contests in which the same effort simultaneously determines the outcome.

Finally, our results may contribute to the literature on internal labor markets and promotion determinants (see Lazear, 1999, 2018).

The paper is organized as follows: The general model is presented in Section 2 and analyzed in Section 3. The experimental setup is introduced in Section 4. Section 5 contains the experimental results. A discussion and conclusion is provided in Section 6. The appendix contains the proofs and complementary results.

2 Model

We consider a winner-take-all contest between n players divided into 2 teams $g \in \{1, 2\}$. Team g comprises m_g players where $m_2 = n - m_1$ and we assume that $m_2 > m_1 \geq 2$. All players compete in a grand contest for the prize $A > 0$. In addition, players may compete in an inter-team contest for prize $B \geq 0$ and in intra-team contests for prizes $C_1 \geq 0$ and $C_2 \geq 0$, respectively.

The outcome of all contests is assumed to be simultaneously determined by a single effort choice of each player. Each player has a sufficiently large initial wealth endowment $e \in \mathbb{R}_+$. Let $x_{gi} \geq 0$ denote the effort chosen by player i in team g and let $\boldsymbol{x}_{-gi}$ denote the vector of efforts of all other players. To keep the analysis tractable, we assume that chances of winning are given by the contest-success function (CSF) proposed by Tullock (1980),[4] effort costs are linear, and players are risk-neutral. Accordingly, the expected payoff of player i in team g is given by

$$E\pi_{gi}\left(x_{gi}, \boldsymbol{x}_{-gi}\right) := \frac{x_{gi}}{\sum_h \sum_j x_{hj}}\, A + \frac{\sum_j x_{gj}}{\sum_h \sum_j x_{hj}}\, f\left(m_g\right)\, B + \frac{x_{gi}}{\sum_j x_{gj}}\, C_g - x_{gi}, \qquad (1)$$

where the first fraction is assumed to equal $1/n$, the second $1/2$, and the third $1/m_g$, if all efforts in the respective denominator are zero. The function $f : \mathbb{N} \rightarrow [0, 1]$ captures the fraction $f\left(m_g\right)$ of the prize B in the inter-team contest that each member of the successful team g receives. This depends on the nature of the prize and the team's sharing rule. For

[3] See also Dahm (2018) and Matros and Rietzke (2018) for recent theoretical contributions on this kind of overlapping contests.

[4] Tullock's contest success function is a special case of the CSF axiomatized by Skaperdas (1996).

example, $f(m_g) \equiv 1$ if B is a public good such as fame. In contrast, $f(m_g) = 1/m_g$, if B is a private good and shared equally among the team members. Finally, the example $f(m_g) = 1/m_g^2$ may apply if B is a private good and subject to conflict within the winning team.[5] As rivalry and competition are usually fiercer in larger teams, we assume f to be non-increasing. We refer to the above game as the *joint contest*.

3 Theoretical Predictions

Let $X = \sum_h \sum_j x_{hj}$ and $X_g = \sum_j x_{gj}$ for each $g \in \{1,2\}$. Maximizing (1) with respect to x_{gi} yields the FOC

$$\frac{X - x_{gi}}{X^2} A + \frac{X - X_g}{X^2} f(m_g) B + \frac{X_g - x_{gi}}{X_g^2} C_g = 1. \tag{2}$$

We focus on the symmetric-within-teams Nash equilibrium in which players of the same team spend the same effort. Accordingly, equilibrium efforts satisfy $x_{gi}^* = X_g^*/m_g$ for each $i \in T_g$ and each $g \in \{1,2\}$ where T_g denotes the set of the members of team $g \in \{1,2\}$. Equilibrium conditions for the team efforts are then given by

$$\left[\frac{A}{m_g} + f(m_g) B\right] X_g - f(m_g) B X - \frac{m_g - 1}{m_g} C_g \frac{X^2}{X_g} = X A - X^2 \tag{3}$$

for each $g \in \{1,2\}$. Combining the two equations yields

$$\frac{A}{m_1} X_1 - B_1 X_2 - \hat{C}_1 \frac{(X_1 + X_2)^2}{X_1} = \frac{A}{m_2} X_2 - B_2 X_1 - \hat{C}_2 \frac{(X_1 + X_2)^2}{X_2} \tag{4}$$

where $B_g = f(m_g) \cdot B$ and $\hat{C}_g = [(m_g - 1)/m_g] \cdot C_g$ for $g \in \{1,2\}$.

We first consider equilibria where $X_g^* > 0$ for each $g \in \{1,2\}$. By multiplying (4) with X_1 and X_2 and rearranging terms, we obtain

$$0 = X_1^3 \left\{\hat{C}_1 z^3 + \left[\frac{A}{m_2} + B_1 + 2\hat{C}_1 - \hat{C}_2\right] z^2 - \left[\frac{A}{m_1} + B_2 + 2\hat{C}_2 - \hat{C}_1\right] z - \hat{C}_2\right\} \tag{5}$$

where $z = X_2/X_1$. In the appendix we show that the polynomial has a strictly positive root, if and only if either $C_g > 0$ for each $g \in \{1,2\}$, or $C_g = 0$ and $\hat{C}_h < (A/m_h) + B_g$ for $g, h \in \{1,2\}$ and $g \neq h$. Furthermore, the root is unique in these cases and we denote it henceforth by $z^* \equiv z^*(A, B, C_1, C_2, m_1, m_2; f)$ (we omit the arguments for the sake of readability).[6] Given z^*, the equilibrium is straightforwardly derived.

[5] The corresponding subsequent intra-team contest is not modeled explicitly here. For the strategic choice of sharing rules in collective contests see, e.g., Balart et al. (2016).

[6] The explicit expression is available from the authors upon request.

Assume next that $X_g^* = 0$ for some team $g \in \{1, 2\}$. Obviously, this is possible only if $C_g = 0$ since otherwise each player in team g has an incentive to marginally increase her effort to obtain the intra-team prize. Moreover, $X_h > 0$ for team $h \neq g$ by a similar argument regarding the grand (or inter-team) contest. Given $X_g = 0$, the FOC for player i of team $h \neq g$ is given by

$$\frac{X_h - x_{hi}}{X_h^2} A + \frac{X_h - x_{hi}}{X_h^2} C_g = 1.$$

Applying symmetry and rearranging terms yields $X_h^* = \frac{m_h - 1}{m_h} (A + C_h)$. Yet, this may only be an equilibrium if no player in team g has an incentive to exert any effort, i.e., if the marginal utility of player $i \in T_g$ at $x_{gi} = 0$ given X_h^* and $x_{gj} = 0$ for each $j \in T_g \setminus \{i\}$ is non-positive. Using (2) and rearranging terms we find the necessary condition

$$A + f(m_g) \, B \leq X_h^* = \frac{m_h - 1}{m_h} (A + C_h). \tag{6}$$

In summary, we obtain the following solution of the game:

Lemma 1. *The joint contest has a unique symmetric-within-teams Nash equilibrium where $x_{gi}^* = X_g^*/m_g$ for each $g \in \{1, 2\}$ and each $i \in T_g$ and equilibrium team efforts are given as follows:*

(a) Interior Equilibrium: *If (i) $C_g > 0$ for each $g \in \{1, 2\}$ or (ii) $\frac{m_g - 1}{m_g} C_g < \frac{A}{m_g} + f(m_h) \, B$ for each $g \in \{1, 2\}$, where $h = 3 - g$, equilibrium team efforts are given by*

$$X_1^* = \frac{\frac{m_1 - 1}{m_1} + z^*}{(1 + z^*)^2} A + \frac{z^*}{(1 + z^*)^2} f(m_1) \, B + \frac{m_1 - 1}{m_1} C_1 \tag{7}$$

and $X_2^* = z^* \cdot X_1^*$;

(b) Single Team Equilibrium: *If $C_g = 0$ for some $g \in \{1, 2\}$ and $\frac{m_h - 1}{m_h} C_h \geq \frac{A}{m_h} + B_g$ for $h = 3 - g$, equilibrium team efforts are given by $X_g^* = 0$ and $X_h^* = \frac{m_h - 1}{m_h} (A + C_h)$.*

The proof is relegated to the appendix. To interpret this result, we first discuss the cases in which there is (i) no intra-team contest ($B > 0$, $C_1 = C_2 = 0$) and (ii) no inter-team contest ($B = 0$, $C_1, C_2 > 0$), respectively, before returning to the joint contest.

3.1 The Impact of Inter-Team Competition

Assume that $C_g = 0$ for each g to focus on the impact of simultaneous inter-team competition on the grand contest. Plugging this into (5) and solving for z^* yields the equilibrium condition for relative team efforts

$$z^* = \frac{X_2^*}{X_1^*} = \frac{m_2}{m_1} \cdot \frac{A + m_1 f(m_2) B}{A + m_2 f(m_1) B}. \tag{8}$$

Accordingly, the larger team provides the larger team effort, if and only if

$$\left[\frac{1}{m_1} - \frac{1}{m_2}\right] A > [f(m_1) - f(m_2)] B.$$

To provide some examples, this holds, if (i) B is a public good ($f(m_g) \equiv 1$), or (ii) B is a private good and the grand contest is sufficiently important. Concretely, the condition is $A > B$, if private good B is shared equally within the winning team ($f(m_g) = 1/m_g$), and $A/B > (m_1 + m_2)/(m_1 m_2)$, if winnings are contested within the winning team ($f(m_g) = 1/m_g^2$).

Second, as f is non-increasing, (8) also implies that each member of the smaller team provides the higher effort and thus has the better chance of winning in the grand contest (i.e. $X_2/m_2 < X_1/m_1$). To summarize:

Proposition 1. *In the symmetric-within-teams Nash equilibrium of the joint contest without intra-team conflict:*

(a) Members from the smaller team have the higher chance of winning in the grand contest.[7]

(b) The smaller team provides the larger team effort, if and only if (i) $f(m_1) > f(m_2)$ and (ii) the prize in the inter-team contest is sufficiently larger than the prize in the grand contest.

The intuition for these results is simple. The free-riding problem in the inter-team contest is more severe in larger teams since more players may potentially contribute to the team effort. Given that the same effort determines chances in the grand contest, incentives to free-ride spill over to the grand contest and lower a large team member's chances of winning.

The consequences may be substantial. Assume $A = B$ and compare a two-player team ($m_1 = 2$) with a team of eight players ($m_2 = 8$). Compared to a player from the large team, a player in a two-player team is three times as likely to win the grand contest, if B is a public good ($f(m_g) \equiv 1$), and she is four times as likely to win if B is a private good and shared equally within the winning team ($f(m_g) = 1/m_g$). Hence, the need to share the team winnings among a larger number of players exacerbates the disadvantage of members of the larger team. On the other hand, the player in the two-player team is

[7]This holds for any non-increasing f. It also holds, if f is increasing, but strictly concave.

only 2.9 times as likely to win as a player in the eight-player team, if B is a private good that is contested in the winning team ($f(m_g) = 1/m_g^2$). Accordingly, fighting over team winnings may help members of the larger team.[8]

We finally turn to the incentives of a contest designer who is able to set the prizes for the grand and the inter-team contest subject to the constraint $A + B \leq R$. It is immediate that a designer interested in a close grand contest will not combine it with an inter-team contest, i.e. select $B = 0$. On the other hand, a close inter-team contest generally requires to combine the two contests. Finally, a contest designer maximizes total effort by putting all resources into the grand contest. We summarize our results on contest design in the following corollary.

Corollary 1. *A contest designer with budget $R > 0$ who maximizes*

(a) total equilibrium effort $X^* = \sum_g \sum_i x_{gi}^*$, will select $A = R$ and $B = 0$;

(b) closeness of the grand contest $C_{GC} := -\max_{g,i} \left| x_{gi}^*/X^* - 1/n \right|$, will select $A = R$ and $B = 0$;

(c) closeness of the inter-team contest $C_{TC} := -\left| X_1^* - X_2^* \right|$, will select

$$A = \frac{f(m_1) - f(m_2)}{f(m_1) - f(m_2) + (1/m_1) - (1/m_2)} \cdot R$$

and $B = R - A$.

Part (a) of the corollary shows that the grand contest provides better incentives to elicit individual efforts than the team contest. Furthermore, combining the grand contest with an inter-team contest (Part (b)) introduces a discrimination mechanism into an otherwise fully symmetric environment. On the other hand, as shown in Part (c) of the corollary, introducing a grand contest in a setting of inter-team competition can outweigh the disadvantage of larger groups that results from larger free riding. Conversely, inter-team competition improves the likelihood of smaller teams to have *any* member win in the grand contest. In general, for a contest designer interested in closeness of the inter-team contest (or equivalently, of the two teams' performances), there is an optimal distribution of the budget which depends on the team sizes, the nature of the prize B in the inter-team contest, and the sharing function $f(\cdot)$. If B is a public good, the inter-team contest is maximally close ($X_1^* = X_2^*$) and adding a grand contest only favors the larger team. If B is a private good and shared equally within the winning team ($f(m_g) = 1/m_g$), the optimal allocation of the budget is given by $A = B = R/2$. Finally, less resources must

[8] Notice however that the relative odds of each team (X_g/X_h for team g where $h \neq g$) are increasing in the expression $f(m_g)$. Hence, in a model with team-dependent functions f_1 and f_2, each team prefers an equal distribution of team winnings over fighting over them.

be allocated to the grand contest ($A < R/2 < B$), if B is a private good and contested within the winning team ($f(m_g) = 1/m_g^2$).

3.2 The Impact of Intra-Team Competition

We assume next that $B = 0$ and analyze the impact of simultaneous intra-team competition on the grand contest. It follows that z^* is the unique positive root of the cubic polynomial

$$\hat{C}_1 \, z^3 + \left[\frac{A}{m_2} + 2\,\hat{C}_1 - \hat{C}_2\right] z^2 - \left[\frac{A}{m_1} + 2\,\hat{C}_2 - \hat{C}_1\right] z - \hat{C}_2,$$

where $\hat{C}_g = [(m_g - 1)/m_g] \; C_g$ for $g \in \{1, 2\}$. The properties of z^* yield the following results:

Proposition 2. *In the symmetric-within-teams Nash equilibrium of the joint contest without inter-team conflict:*

(a) Members from the smaller team have the higher chance of winning in the grand contest if and only if $C_1/C_2 > \left(\frac{m_1}{m_2}\right)^2 \frac{m_2-1}{m_1-1}$ *or equivalently if* $C_1/m_1 > \frac{m_1}{m_2} \frac{m_2-1}{m_1-1} (C_2/m_2)$*. Accordingly, ceteris paribus, the prize* C_2 *in the intra-team contest required to maintain parity in the grand contest increases (asymptotically linearly) in the team size* m_2*.*

(b) The smaller team provides the larger team effort, if and only if $C_1 > \frac{m_1}{m_2} \frac{m_2-1}{m_1-1} C_2 + \frac{m_2 - m_1}{m_2 (m_1-1)} \frac{A}{4}$*.*

Again, the intuition for the results is simple. The intra-team contest is more severe in larger teams and expected winnings for each dollar of prize money are lower.[9] As before, these incentives spill over to the grand contest, lowering the chances of winning for members of the larger team. In this case, however, it is likely that the prize money for the intra-team contest (*intra-team prize* henceforth) is determined independently by each team. Each team (or the corresponding contest designer) may therefore increase the intra-team prize sufficiently to avoid the disadvantage for its members. The proposition makes these conditions explicit. We discuss them in turn below.

Consider first the players' chances of winning the grand contest. As shown in the first part of Proposition 2, a member of the small team has a higher chance of winning the grand contest than a member of the large team, if the intra-team prize in the small team is sufficiently large compared to the intra-team prize in the large team. Reassuringly, the small team must spend less than the large team to maintain parity. However, the necessary intra-team prize *per capita* is larger in the small than in the large team, where the difference is the smaller, the larger is the small team and the smaller is the large team. For example, a team of two players ($m_1 = 2$) must spend (approximately) twice as much per capita when competing against a very large team.

[9] This holds not only for the Tullock contest with linear effort costs considered here, but also for general winner-take-all contests with convex effort costs and additive noise when the noise density is decreasing or unimodal and symmetric; see, e.g., Gerchak and He (2003) or Drugov and Ryvkin (2019).

With $m_1 = 11$, it suffices to spend ten percent more per capita than the other team regardless of its size.

Turning to team efforts in equilibrium, notice that the team effort directly translates into the chance that *any* member from the team wins the grand contest, and may therefore be an important objective for the designer of the intra-team contest. Absent the intra-team contests, the smaller team provides a lower team effort simply due to its size. Accordingly, the smaller team needs to set the intra-team prize sufficiently high to overcome this disadvantage: The lower bound for C_1 is strictly positive even if $C_2 = 0$. Furthermore, the lower bound is decreasing in the smaller team's size, increasing in the larger team's size, and approaches a limit equal to $A/\left[4 \cdot (m_1 - 1)\right]$ as m_2 grows large. Hence, regardless of the team sizes, setting up an additional intra-team contest with a prize of at least one quarter of the grand prize is sufficient to outweigh the initial disadvantage of the smaller team.

As a consequence, even to achieve a higher equilibrium team effort than the small team, the large team must set up an intra-team contest and offer an intra-team prize comparable to the intra-team prize of the small team. This holds especially if both teams are large. For instance, for two teams with 50 and 100 players, respectively, the large team must offer at least 98 percent of the small team's intra-team prize in its own intra-team contest. The smaller (larger) the size of the small (large) team, the lower this prize money may be. Regardless of the team sizes, the large team must offer at least $C_1/2 - A/8$.

3.3 The Joint Impact of Inter- and Intra-Team Competition

The above sections show that a simultaneous inter- or intra-team competition each lowers the chances of winning in the grand contest for members of the larger team. A combination of all three contests is thus least favorable for the large team. Indeed, we obtain that the larger team may need to spend more prize money per capita in the intra-team contest to guarantee parity for its members in the grand contest.

Proposition 3. *In the symmetric-within-teams Nash equilibrium of the joint contest:*

(a) Members from the smaller team have the higher chance of winning in the grand contest if and only if the prizes per capita in the intra-group contest satisfy

$$\frac{C_1}{m_1} > \frac{m_1}{m_2}\,\frac{m_2 - 1}{m_1 - 1}\,\frac{C_2}{m_2} - \frac{m_1}{m_1 - 1}\,\frac{m_2\, f\left(m_1\right) \; - \; m_1\, f\left(m_2\right)}{\left(m_1 \; + \; m_2\right)^2}\, B.$$

Accordingly, the larger team must offer a higher prize per capita in the intra-team contest than the small team to guarantee its members equal chances of winning in the grand contest, if

$$\frac{C_1}{m_1} < \frac{m_1\, m_2}{\left(m_1 \; + \; m_2\right)^2}\,\frac{m_2\, f\left(m_1\right) \; - \; m_1\, f\left(m_2\right)}{m_2 \; - \; m_1}\, B. \tag{9}$$

(b) The smaller team provides the larger team effort, if and only if

$$C_1 > \frac{m_1}{m_2}\,\frac{m_2 - 1}{m_1 - 1}\, C_2 + \frac{m_2 - m_1}{\left(m_1 - 1\right)\, m_2}\,\frac{A}{4} - \left[f\left(m_1\right) \; - \; f\left(m_2\right)\right]\, B.$$

The proposition illustrates how the combination of the grand contest with an inter- and an intra-team contest puts the large team at a drastic disadvantage, and makes it very costly for the designer of the large team's intra-team contest to achieve parity for its members. The results hold whenever the prize in the small team's intra-team contest is not too large. The upper bound, given in equation (9), is increasing in the prize for the inter-team contest (B), and it increases, as the difference between $f(m_1)$ and $f(m_2)$ gets larger. Hence, the more important the inter-team contest and the more severe the conflict which ensues over winnings in the inter-team contest, the more the large team needs to offer in the intra-team contest to maintain its members' chances in the grand contest. In addition, we also find that the upper bound on C_1/m_1 increases (decreases) in the size of the small (large) team for the examples $f(m) = 1$, $f(m) = 1/m$, and $f(m) = 1/m^2$.

Finally, Lemma 1 also shows how the intra-team prize may be used to fully deter competition from an opposing team who does not induce an intra-team contest itself. Concretely, by selecting a sufficiently large intra-team prize, team $g \in \{1, 2\}$ induces a degree of competition by its own members which is so large – even in the absence of competition from the other team – that the marginal utility of effort is negative for each member of the opposing team $h = 3 - g$. Hence, members of team h prefer to abstain from the competition altogether. Notice that such a deterrence is possible for every team regardless of its size. Yet, larger teams must invest less to induce this equilibrium as the lower bound on the intra-team prize is decreasing in the team size.

4 Experimental Design and Procedures

We test the theoretical predictions derived in Section 3 with the help of an experiment. Indeed, various factors not accounted for in the model may affect behavior and thus counteract the effects identified above. In particular, the experimental literature on contests between teams shows that members of larger groups tend to overbid more relative to Nash equilibrium than members of small groups (Sheremeta, 2018). As a consequence, the "group size paradox" (see e.g. Katz and Tokatlidu, 1996, Baik and Lee, 1997) which predicts that smaller groups are more likely to win in inter-group contests than larger groups because of less free-riding often does not materialize in the laboratory. One explanation is that *group identity* becomes salient in contests between groups and increases subjects' *parochial altruism*, i.e. the extent to which they care about the payoffs of members of their own group as opposed to members of the other group (see e.g Abbink et al., 2012, Chowdhury et al., 2016). It is not clear *a priori* how the combination of an inter-team contest with a grand contest affects subjects' identity and therefore their parochial altruism. At the extreme, subjects may care mainly about the grand contest which limits the degree to which properties of the inter- (or intra-) team contest spill over to the grand contest.

In addition, overbidding relative to Nash equilibrium is also increasing in the group size in intra-group contests (see Sheremeta, 2013). The difference in individual efforts between members of small and large teams is thus often smaller than predicted in the absence of an additional grand contest, and may become negligible when the latter is added.

An experiment enables us to investigate such potential deviations from the theory in a controlled environment. In this section, we describe the design and procedures of the experiment. The experimental results are presented in Section 5.

4.1 General Features

Our experiment consists of two treatments and six sessions. In each session, subjects play 20 repetitions (henceforth *rounds*) of a six-player Tullock contest overlapping with either an inter-team contest (treatment *BETWEEN*) or an intra-team contest (treatment *WITHIN*). The two teams constituting the group comprise two and four subjects, respectively. Throughout rounds, we fix whether a subject is assigned to the small or the large team. In contrast, we randomly assign the subjects to the groups in each round to avoid repeated-game effects.

In each round, each subject makes a single effort choice which simultaneously determines her chances of winning in the grand contest and either the inter- or the intra-team contest. To do so, each subjects is endowed with $E = 400$ points in each round. The prizes for the contests are selected such that the predicted efforts for members of the small and the large team are sufficiently different. Concretely, all subjects compete for a prize of size $A = 600$ points in the grand contest. Subjects in treatment *BETWEEN* additionally compete in an inter-team contest for a prize of size $B = 600$ points which is split equally among the members of the winning team. Each subject in treatment *WITHIN* additionally competes with her team members in an intra-team contest for a prize of size $C_t = 300$ points where $t \in \{A, B\}$, $m_A = 2$, and $m_B = 4$.

The experiment enables us to control for factors potentially influencing subjects' effort choices. One factor that has been found to considerably affect behavior in contests is risk aversion. We therefore measure risk preferences at the beginning of the experiment.[10] We employ a multiple price list format (see e.g. Holt and Laury, 2002). Each subject is presented with a table of ten ordered decisions between a safe amount of 180 points and a risky lottery which offers either 400 points or 0 points. Across the table, the likelihood of receiving the 400 points increases from 0.1 in the first row to 1.0 in the last row in steps of 0.1 (hence, the probability of receiving the 400 points in row k equals $k/10$).[11] Subjects are required to select one of the options in each row (we did not allow for indifference). For a subject who maximizes expected utility and has a strictly increasing utility function, there exists a unique row such that the subject chooses the risky lottery in this and all subsequent rows and the safe amount in all previous rows. The subject's risk preferences may thus be summarized by the number of times she chooses the safe lottery.

In addition to risk preferences we collect several demographics (age, gender, academic major, and mother tongue) as well as self-assessments of certain characteristics with the help of a questionnaire at the end of each session.[12]

[10] Obviously, this design feature relies on the assumption that risk-preferences are not context-dependent.

[11] In the experimental instructions, probabilities are explained in terms of throws of a ten-sided dice.

[12] Concretely, we elicit self-assessments on risk, generosity, ambition, frequency of participation in games of chance and board games, importance of winning either contest, and importance of the final

4.2 Procedures

Three sessions were conducted for each treatment. The sessions took place at the experimental laboratory of the University of Bamberg in July and November 2018. Students from the University of Bamberg were invited using the ORSEE recruitment system (Greiner, 2015). 18 subjects participated in each session. The experiment was programmed in zTree (Fischbacher, 2007).

Each experimental session was partitioned into two parts. Upon arrival at the lab, subjects were randomly assigned to cubicles that did not allow for any visual communication between them. Subjects were immediately asked to read the basic instructions provided in their cubicle which informed subjects about the general rules for behaviour in the laboratory, that there were going to be two parts, and that the corresponding instructions were going to be distributed at the beginning of each part.[13]

In the first part, we elicited subjects risk preferences using the multiple price list format as described above. Subjects first received paper instructions and were given time to read them at their own pace. Instructions were then read aloud and subjects were permitted to ask questions. Afterwards, each subject was presented with the table of ten decisions on the computer screen and asked to submit her choices via the computer. We made clear to subjects that only one of the ten decisions would be payoff-relevant, and that it would be selected by a random draw at the end of the experiment.

The contests were run in the second part of the experiment. Paper instructions for the second part were distributed once all subjects had submitted their ten decisions in the first part. Subjects were again given time to read them at their own pace before the instructions were read aloud. Instructions for part 2 were followed by a short quiz to check subjects' understanding. The experimenters controlled subjects' answers and explained mistakes in private if necessary. Afterwards, the 20 rounds of part 2 were run. Subjects submitted their efforts using the computer. To assist them in their decision-making, the computer interface also offered subjects the opportunity to enter a fictitious effort for themselves as well as fictitious average efforts for the other members of their own team and the members of the other team. The interface then displayed the resulting likelihoods of winning and losing each of the two contests and the corresponding number of points at the end of the round. We paid only two randomly selected rounds for the second part, one round each from the first and the last ten rounds.

Upon completion of the second part, one of the subjects was selected to role a ten-sided dice four times. The first and second throw determined, respectively, the payoff-relevant row and the payoff of the corresponding risky lottery in the first part of the experiment. The third and fourth throw determined the payoff-relevant rounds in the second part of the experiment. Subjects then filled out the questionnaire, retrieved their earnings in private and left.

payment on a 7 point Likert scale. In addition, we ask subjects which team they think is advantaged in this experiment (small, large, or none), and which contest affected their effort choices the most (grand contest, team contest, or both equally).

[13]The experimental instructions were originally given in German. We provide them (upon request) in a separate document which includes also an English translation as well as the screenshots of the computer-assisted experiment.

TABLE 1
PREDICTIONS FOR THE LABORATORY GAMES.

	BETWEEN		*WITHIN*	
Team Size	Small	Large	Small	Large
Individual Efforts (Points)	150	75	168	134
Team Efforts (Points)	300	300	336	537
Pr(Win): Grand Contest	0.250	0.125	0.192	0.153
Pr(Win): Inter-Team Contest	0.500	0.500	—	—
Pr(Win): Intra-Team Contest	—	—	0.500	0.250
Expected Payoff (Points)	550	475	497	433

Sessions lasted 90 minutes on average. Points were converted into cash at the rate 1 point = €0.01 and added to a show-up fee of €4.00. The average payment was €15.02 in treatment *BETWEEN*, and €14.95 in treatment *WITHIN*. Overall, we collected 2,160 effort choices submitted by 108 subjects.

4.3 Hypotheses

Table 1 presents predicted efforts, winning probabilities, and expected payoffs by team size for the two games played, respectively, in treatment *BETWEEN* and *WITHIN*. From these results, we derive the following hypotheses:

Hypothesis 1. *In both treatments, members of the smaller team invest more than members of the larger team. The difference is larger in treatment* BETWEEN.

Hypothesis 2. *The team effort of the smaller team is smaller than the team effort of the larger team in treatment* WITHIN, *but not in treatment* BETWEEN.

Hypothesis 3. *In both treatments, members of the smaller team have a better chance of winning the grand contest and achieve a higher payoff than members of the larger team.*

5 Experimental Results

Figure 1 plots average individual efforts across rounds where the left (right) panel contains the results for treatment *BETWEEN* (*WITHIN*), and in each panel, the solid blue (orange) line depicts results for members of the small (large) team.[14] We also include dashed lines (of corresponding color) to highlight the theoretical predictions.

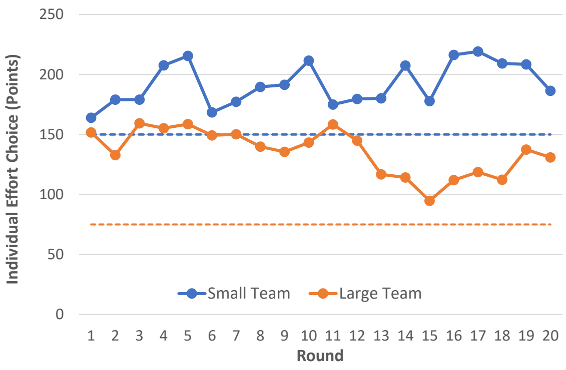
We find serious overbidding in treatment *BETWEEN*. Across all (the last ten) rounds, members of the small team invest on average 192 (196) points and thus significantly more than the equilibrium prediction of 150 points ($p < 0.001$).[15] Similarly, members of the large team

[14] Recall that subjects consistently belong either to the small or to the large team across rounds.

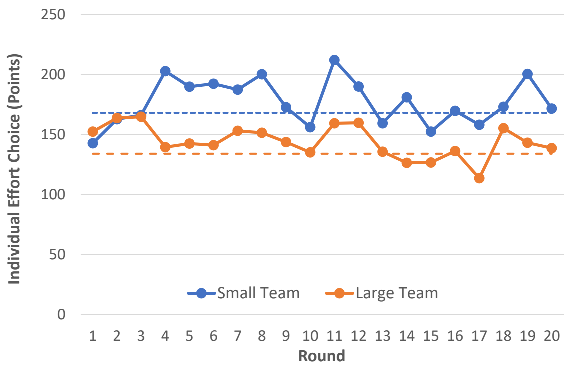
[15] To test for significance, we estimate a random-effects model with a constant and a dummy for the large team, and standard errors clustered at the session level. Similar results are obtained when using a Tobit model. All results are available from the authors upon request.

FIGURE 1

Average efforts across rounds by treatment and role.



(a) Treatment *BETWEEN*



(b) Treatment *WITHIN*

invest on average 136 (124) points across all (the last ten) rounds, significantly more than the predicted 75 points ($p < 0.001$). In contrast, average efforts in treatment *WITHIN* are not significantly larger than the equilibrium prediction for members of both teams both when considering all rounds (177 vs. 168 for the small team; 144 vs. 134 for the large team), and only the last ten rounds (177 vs. 168 and 139 vs. 134 for the small and large team, respectively). Accordingly, we (only) partially confirm the recurrent finding in the literature that subjects overbid in contest experiments.

Turning to our first hypothesis, Figure 1 suggests that subjects in the small team invest more than subjects in the large team in both treatments. To statistically test this impression, we estimate random-effect Tobit models of effort choices.[16] We include as explanatory variables a dummy for the large team, a dummy for the first ten rounds, and the interaction between the two. In further specifications, we also control for the number of safe choices in the first part of the experiment as well as demographics and self-assessments elicited through the questionnaire. The results are presented in Table 2. Coefficients of the questionnaire variables are only shown, if they are significantly different from zero in at least one of the treatments.

The results for treatment *BETWEEN* clearly show that members of the large team invest significantly less than members of the small team. In contrast, the difference is marginally significant in treatment *WITHIN*, and disappears completely once we control for demographics and other results from the questionnaire. Additional findings reveal that the latter result (or lack thereof) is mainly driven by certain subgroups of subjects. In particular, students of the social sciences and humanities invest significantly *more* as members of the large team than as members of the small team. We summarize these findings as follows:

Result 1. *In line with the theoretical predictions, members of the small team invest significantly more than members of the large team in treatment* BETWEEN. *In contrast, the result only holds for an (identifiable) subgroup of the subjects in treatment* WITHIN.

[16]There are several choices at the boundary of the choice set. We obtain similar results when running standard Tobit regression with standard errors clustered at the session level.

TABLE 2

RANDOM-EFFECTS TOBIT MODELS FOR INDIVIDUAL EFFORT CHOICES.

Treatment	*BETWEEN*			*WITHIN*		
Model	(1)	(2)	(3)	(4)	(5)	(6)
Constant	197.55***	334.72***	282.17***	174.69***	288.47***	189.17*
	(25.42)	(64.69)	(55.16)	(26.21)	(62.87)	(97.11)
Large	-81.13***	-88.15***	-112.80***	-46.86	-56.11*	6.90
	(31.18)	(29.97)	(24.96)	(32.03)	(31.37)	(30.88)
First10	-12.40	-12.38	-12.42	2.76	2.75	2.81
	(12.06)	(12.06)	(12.07)	(12.45)	(12.45)	(12.45)
First10 × Large	41.91***	41.86***	42.00***	12.49	12.52	12.54
	(14.85)	(14.86)	(14.87)	(15.16)	(15.16)	(15.16)
NbS		-24.93**	-5.02		-20.34**	-11.61
		(10.89)	(7.24)		(10.28)	(9.34)
Further Controls	No	No	Yes	No	No	Yes
Freq. Gambling			15.32**			7.00
			(7.47)			(10.12)
Generosity			16.93***			-4.08
			(6.49)			(10.44)
Imp. Payment			-26.43***			-2.87
			(6.96)			(9.81)
Imp. GC			25.88***			35.05***
			(7.30)			(10.97)
Log-likelihood	-5,552.3	-5,549.8	-5,516.9	-5,499.3	-5,497.4	-5,478.9
Wald χ^2	16.61***	22.21***	152.02***	4.85	8.88*	62.99***

Notes: There are 137 (152) left-censored, 859 (849) uncensored, and 84 (79) right-censored observations in models 1–3 (4–6). Standard errors in parentheses. Significance levels: *** (1%), ** (5%), * (10%). Continuous demographic variables (age, number of siblings, grade in math) and questionnaire variables measured on a Likert scale are normalized as differences from the median.

The results from the Tobit regressions also reveal distinct dynamics of effort choices in the two treatments and for the two roles. In treatment *BETWEEN*, members of the small team slightly increase their efforts over time, and members of the large team substantially and significantly decrease their efforts over time. As a consequence, the difference between small and large teams widens over time. In treatment *WITHIN*, only members of the large team slightly decrease their efforts over time whereas members of the small team keep investing similar amounts across rounds.

Finally, we find that subjects who are less risk-averse and subjects who care more about the grand-contest invest more.

We now turn to team efforts and our second hypothesis. In treatment *BETWEEN*, we find that the average team effort of the small team equals 384 points and is thus substantially smaller than the average team effort of the large team (543 points). Similarly, the average team effort of the small team in treatment *WITHIN* equals 354 points compared to an average team effort of the large team equal to 576 points. These results are in line with theoretical predictions for the latter but not the former treatment. To summarize:

TABLE 3
EXPERIMENTAL RESULTS BY TREATMENT AND TEAM SIZE.

	BETWEEN		*WITHIN*	
Team Size	Small	Large	Small	Large
Average Individual Efforts (Points)	192.2	135.8	177.0	144.1
Average Team Efforts (Points)	384.3	543.2	354.0	576.3
Theoret. Pr(Win): Grand Contest	0.209	0.146	0.198	0.151
Empirical Pr(Win): Grand Contest	0.228	0.136	0.208	0.146
Theoret. Pr(Win): Inter-Team Contest	0.417	0.583	—	—
Empirical Pr(Win): Inter-Team Contest	0.400	0.600	—	—
Realized Payoffs: Part 2	€9.56	€8.34	€10.05	€8.46
Realized Payoffs: Overall	€11.64	€10.70	€11.89	€10.48

Result 2. *In both treatments, the team effort of the small team is substantially smaller than the team effort of the large team.*

The average effort choices summarized above have serious consequences for probabilities of winning the grand contest, and earnings. Following Table 1, Table 3 provides an overview of the experimental results for the last ten rounds. The first two rows restate the results regarding individual and team efforts we discussed above. The third row presents the average probabilities of winning the grand contest calculated from the effort choices of our subjects. These results reflect the findings for effort choices: In both treatments, members of the small team are more likely to win the grand contest. The fourth row shows that the empirical frequencies calculated from the actually observed contest outcomes exhibit a similar pattern. In treatment *BETWEEN* (*WITHIN*), the grand contest was won 82 (75) times by a member of the small team and 98 (105) times by a member of the large team. Dividing these numbers by the total number of contests and the team size yields the entries in the fourth row of the table. A similar exercise for the inter-team contest in treatment *BETWEEN* reveals that the members of the small team were less successful in this contest than members of the large team. These results are presented in the fifth and sixth row.[17] Finally, the last two rows reveal the payoff consequences of the contest design. In both treatments, subjects assigned to the small teams earn about one euro more than subjects assigned to the large teams.

We summarize the consequences for our final hypothesis in the following result:

Result 3. *In both treatments, members of the smaller team win the grand contest more often than members of the larger team, and they achieve higher earnings.*

6 Discussion and Conclusion

In many everyday situations such as at the workplace or in sports competitions, subjects are simultaneously involved in multiple contests whose outcome depends on the same effort choice of an individual. This paper shows that such overlapping contests adversely affect the chances of

[17]Obviously, we cannot repeat this exercise for the intra-team contest.

winning in the grand contest for members of larger teams. First, the free-riding problem is more severe in an additional contest between teams. Second, competition in an additional intra-team contest is tougher in larger teams. Both effects spill over to the grand contest with the given interdependent incentive structure.

The results of the paper have important consequences for the design of overlapping contests, and also hierarchies. In particular, if an intra-team contest is desired but not supposed to affect chances of winning in the grand contest, prizes in each team should be set proportional to the team size.

The paper offers several avenues for future research. One question is whether, in the presence of intra-team contests, larger teams anticipate the potential disadvantage and set the prize for the intra-team contest sufficiently high to maintain the chances of their members. Ultimately, this yields a meta-game between teams in which each team attempts to maximize the chances of its members by choosing the optimal prize for the intra-team contest. It would be interesting to study the outcome of this game both theoretically and experimentally.

In addition, our findings also raise empirical questions to be answered in the field. In particular, one may ask whether, controlling for all other factors, employees in smaller units of firms have a better chance of being promoted.

Appendix

Proof of Lemma 1. We start by determining the roots of the cubic polynomial

$$Q(z) \;=\; \hat{C}_1\, z^3 \,+\, \left[\frac{A}{m_2} \,+\, B_1 \,+\, 2\,\hat{C}_1 \,-\, \hat{C}_2\right]\, z^2 \,-\, \left[\frac{A}{m_1} \,+\, B_2 \,+\, 2\,\hat{C}_2 \,-\, \hat{C}_1\right]\, z \,-\, \hat{C}_2$$

in equation (5). Consider first the case $C_g > 0$ for each $g \in \{1,2\}$. It is easily seen that $Q(0) = -\hat{C}_2 < 0$, and $Q(z) \to \pm\infty$ as $z \to \pm\infty$. Furthermore, from the first derivative

$$Q'(z) \;=\; 3\,\hat{C}_1\, z^2 \,+\, 2\,\left[\frac{A}{m_2} \,+\, B_1 \,+\, 2\,\hat{C}_1 \,-\, \hat{C}_2\right]\, z \,-\, \left[\frac{A}{m_1} \,+\, B_2 \,+\, 2\,\hat{C}_2 \,-\, \hat{C}_1\right]$$

we obtain that $Q(z)$ either reaches a maximum at $z_{max} < 0$ or is strictly increasing everywhere. Hence, there is a unique strictly positive root $z^* > 0$.

Second, let $C_1 = 0$. The polynomial then becomes quadratic and there are three cases: If $C_2 = 0$, the roots are given by $z_1 = 0$ and $z_2 = z^* = \left(\frac{A}{m_2} + B_1\right) / \left(\frac{A}{m_1} + B_2\right) > 0$. Notice that z_1 cannot support an equilibrium because of the necessary condition (6) derived in the text. If $0 < \hat{C}_2 < (A/m_2) + B_1$, the quadratic polynomial satisfies $Q(0) < 0$ and $Q(z) \to \infty$ as $z \to \pm\infty$ and therefore has a unique strictly positive root $z^* > 0$. Finally, if $\hat{C}_2 \geq (A/m_2) + B_1$, then $Q(z) < 0$ for each $z \geq 0$.

Third, let $C_2 = 0$ and $C_1 > 0$. Then

$$Q(z) \;=\; z \,\cdot\, \left\{\hat{C}_1\, z^2 \,+\, \left[(A/m_2) \,+\, B_1 \,+\, 2\,\hat{C}_1\right]\, z \,-\, \left[(A/m_1) \,+\, B_2 \,-\, \hat{C}_1\right]\right\}$$

with roots $z_1 = 0$, and

$$z_{2,3} \;=\; \frac{1}{\hat{C}_1}\left[-\left(\frac{A}{m_2} \,+\, B_1 \,+\, 2\,\hat{C}_1\right) \,\pm\, \sqrt{\left(\frac{A}{m_2} \,+\, B_1 \,+\, 2\,\hat{C}_1\right)^2 \,+\, \hat{C}_1^2\,\left(\frac{A}{m_1} \,+\, B_2 \,-\, \hat{C}_1\right)}\,\right].$$

There are two cases: If $\hat{C}_1 < \frac{A}{m_1} + B_2$, then $z_2 < 0 < z_3 = z^*$. In contrast, if $\hat{C}_1 \geq \frac{A}{m_1} + B_2$, then $z_2 < z_3 \leq 0$.

Assume now that a strictly positive root $z^* > 0$ of $Q(z)$ exists. Plugging $X_2 = z^* \cdot X_1$ into (2) for $g = 1$ yields

$$\frac{(1+z^*)\;X_1 \,-\, \frac{1}{m_1}\,X_1}{(1+z^*)^2\;X_1^2}\;A \,+\, \frac{z^*\,X_1}{(1+z^*)^2\;X_1^2}\;f\,(m_1)\;B \,+\, \frac{m_1 - 1}{m_1}\,\frac{X_1}{X_1^2}\,C_1 \;=\; 1$$

and thus immediately the equilibrium team efforts. Notice that $X_g^* > 0$ for each $g \in \{1,2\}$. To prove that these team efforts constitute an equilibrium, we show that they induce a strictly positive expected payoff for each player in each team which rules out that players could do better by abstaining from the joint contest. Accordingly, the expected payoff of player i in team $g = 1$

is given by

$$E\pi_{1i}\left(X_1^*/m_1, X_2^*/m_2\right) = \frac{X_1^*/m_1}{\left(1+z^*\right)\, X_1^*}\, A + \frac{1}{1+z^*}\, f\left(m_1\right)\, B + \frac{C_1}{m_1} - \frac{X_1^*}{m_1}$$

which is strictly positive, if and only if

$$\frac{1}{1+z^*}\,\frac{A}{m_1} + \frac{1}{1+z^*}\, f\left(m_1\right)\, B + + \frac{C_1}{m_1}$$
$$> \frac{X_1^*}{m_1} = \frac{\frac{m_1-1}{m_1} + z^*}{\left(1+z^*\right)^2}\,\frac{A}{m_1} + \frac{z^*}{\left(1+z^*\right)^2}\,\frac{f\left(m_1\right)\, B}{m_1} + \frac{m_1-1}{m_1}\,\frac{C_1}{m_1}.$$

This follows from $\left(m_1-1\right)/m_1 < 1$ and $z^* < 1+z^*$. The proof for $g=2$ is similar using $v^* = 1/z^*$ and thus omitted.

Finally, the arguments given in the main text show that (i) there is no other equilibrium, if a strictly positive root of $Q(z)$ exists, and (ii) there exists a unique equilibrium satisfying $X_g^* = 0$ for some $g \in \{1, 2\}$, if $Q(z)$ does not possess a strictly positive root. □

Proof of Corollary 1. **Ad (i)**: Plugging $C_1 = 0$ and $z^* = \frac{m_2}{m_1} \cdot \frac{A+m_1\, f(m_2)\, B}{A+m_2\, f(m_1)\, B}$ into equation (7) and rearranging, we obtain

$$X_1^* = \frac{m_1\, A + m_1\, m_2\, B_1}{\left(m_1+m_2\right)\, A + m_1\, m_2\, \left(B_1+B_2\right)}\left[A + \frac{m_1\, m_2\, B_1\, B_2 - A^2}{\left(m_1+m_2\right)\, A + m_1\, m_2\, \left(B_1+B_2\right)}\right].$$

It follows that the total equilibrium effort is given by

$$X^* = A + \frac{m_1\, m_2\, B_1\, B_2 - A^2}{\left(m_1+m_2\right)\, A + m_1\, m_2\, \left(B_1+B_2\right)}.$$

Selecting $A = (1-\theta)\cdot R$ and $B = \theta \cdot R$ for $0 \leq \theta \leq 1$ and rewriting yields

$$X^* = \frac{m_1\, m_2\, f_1\, f_2\, \theta^2 + \left(m_1+m_2-1\right)\, \left(1-\theta\right)^2 + m_1\, m_2\, \left(f_1+f_2\right)\, \theta\, (1-\theta)}{m_1\, m_2\, \left(f_1+f_2\right)\, \theta + \left(m_1+m_2\right)\, (1-\theta)}$$

where $f_g = f\left(m_g\right)$. The results follows because the expression is strictly decreasing in θ. To see this, differentiate with respect to θ and note that the resulting denominator is positive everywhere whereas the numerator is a quadratic function in θ which has a positive squared term and is negative at $\theta = 0$ and $\theta = 1$.

Ad (ii): Obviously, $B = 0$ yields $x_{gi}^* = \frac{n-1}{n^2} A$ and thus $x_{gi}^*/X^* = 1/n$ for each g and i. On the other hand, equation (8) implies that $x_{2i}^*/x_{1j}^* < 1$ and thus $x_{2i}^*/X^* < 1/n$ for each player i in team 2.

Ad (iii): Equation (8) implies that $X_2^* = X_1^*$, if and only if $f\left(m_1\right) > f\left(m_2\right)$ and $\left(m_2 - m_1\right)\, A = m_1\, m_2\, \left[f\left(m_1\right) - f\left(m_2\right)\right]\, B$. If $f\left(m_1\right) = f\left(m_2\right)$, the RHS of equation (8) is strictly larger than one and decreasing in B. Hence, the optimal contest satisfies $A = 0$ and $B > 0$. $\square$

Proof of Proposition 2. **Ad. (i)**: A member from the smaller team has a better chance of winning in the grand contest than a member from the larger team, if she provides the larger effort. In equilibrium, this happens, if $X_1^*/m_1 > X_2^*/m_2$, i.e. if $z^* < m_2/m_1$. This is equivalent to requiring that the polynomial on the RHS of equation (5) with $B = 0$ is strictly positive at $z = m_2/m_1$. The result follows by re-arranging terms.

Ad. (ii): The small team provides a larger equilibrium team effort than the large team, if $X_1^* > X_2^*$ which is equivalent to requiring that $z^* < 1$, or that the polynomial on the RHS of equation (5) with $B = 0$ is strictly positive at $z = 1$. Re-arranging terms yields the result. $\square$

Proof of Proposition 3. The proof is similar to the proof of Propostion 2. In particular, the first (respectively second) part follows from the requirement that the polynomial on the RHS of equation (5) is strictly positive at $z = m_2/m_1$ (resp. $z = 1$). $\square$

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