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Private-information group contests: Best-shot competition[☆]

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ABSTRACT

We model competing groups when players' values for winning are private information, each group's performance equals the best effort ("best shot") of its members, and the group with the best performance wins the contest. At the symmetric equilibrium of symmetric contests, increasing the number of competing teams may increase or decrease each team's performance, but it unambiguously increases the overall expected best shot. Depending on the elasticity of the distribution of players' values, individual, team, and contest performance may increase or decrease with team size. Considering just two competing groups that differ only in size, we show members of the smaller group use the more aggressive strategy, but, depending on the nature of uncertainty, either team may be more likely to win. More generally, when teams' value cdfs differ, increasing one team's size decreases (increases) that team's chance of winning if *its* value cdf is elastic (inelastic).

1. Introduction

Group competition abounds. One sees it in trade association advertising (e.g., buy *California* wine!), industry groups lobbying for weaker pollution standards while environmental groups lobby for stricter regulation, pharmaceutical research labs competing to find a revolutionary weight-loss drug, and virtually any team sporting event. In these and many other instances, an individual exerts effort to help his team win, and a member of the winning group may enjoy the victory even if he himself exerted little effort. Such an individual faces a dilemma: should he increase his effort in hopes of increasing his team's chance of winning, or should he free ride on his teammates to save on personal effort costs?

To examine how individual incentives depend on group size and the number of competing groups, we model group competition as a contest. Our primary innovation is to address these issues in a model of private information where motivations of others—teammates and rivals—are only imperfectly known.

The study of group contests naturally extends the well-developed models of individualistic contests in which, given players' efforts, an individual winner is determined according to a contest success function (csf). According to "imperfectly discriminating" csfs, efforts influence the probability that a player might win, but they generally are not determinative.[1] Of these, most prominent is Tullock's "lottery" csf, which specifies that each player's chance of winning equals that player's

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[1] Among others, see Tullock (1980), Dixit (1987), and Hirshleifer (1989).

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own effort relative to the total effort exerted in the contest. Alternative models known as "all-pay auctions" use a "perfectly discriminating" csf, which specifies the winning player as the one who exerts greatest effort.[2]

Two strains of group contest literature can be distinguished by whether the contest prize is a private good or a (group-specific) public good. Where the prize is a private good, such as money, researchers have studied inter-group and intra-group incentives, investigating, for example, how rules for allocating the prize within a group influence effort choices at the inter-group competition stage.[3] More relevant for our study is the second strain, which models the prize as a group-specific public good.[4] While larger groups have greater resources at their disposal, they may also face greater scope for free riding, leading Olson (1965) to conjecture that larger groups might perform more poorly in the provision of public goods. This "group-size paradox" has also been studied in contests. Here the seminal paper is by Katz et al. (1990), who found (i) a team's effort did not depend on the number of players per team and (ii) the team whose members had the larger value for winning was the team more likely to win. This lack of dependence on team size hinged on the assumption of constant marginal cost. Allowing for increasing marginal cost of effort, Riaz et al. (1995) and Esteban and Ray (2001) found team size matters: while increasing team size may reduce individual effort, it can increase total team effort. Importantly, all the foregoing group-competition models assume players have perfect information.

In contrast, our essential focus is on how private information affects individual incentives and equilibrium outcomes. The literature provides numerous examples of group conflict, e.g., matches between sports teams, rivalries among military alliances, and competitions involving R&D consortia or legal teams.[5] For most of these environments, assuming complete information is a useful modeling device, but allowing for private information is more realistic. Moreover, private information admits a richer set of behavioral responses, e.g., a change in incentives may induce the same agent to reduce his effort if his value is low, but to increase his effort if his value is high. Finally, a treatment of private information is an essential first step toward understanding issues such as information acquisition and dissemination and contest design for groups.[6]

We make several key assumptions. *First*, the prize is a pure public good for members of the winning team.[7] *Second*, each player's value for the prize is privately known to that player, though *ex ante* the distributions of these values are common knowledge. *Third*, each group's performance equals the group's "best shot," that is, the largest effort exerted among the group's members.[8] *Fourth*, the winning group is the group with the best performance. While only members of the winning group enjoy their private benefits, winners and losers alike incur their effort costs. The first, second, and fourth assumptions are commonly found in models of individualistic or group contests. However, the third deserves comment.

One might instead suggest modeling group performance as a sum of efforts, as is frequently done in the literature on private contributions to public goods[9] and in most of the group-contest models mentioned above. However, this is wholly intractable in a private-information setting, as a player must then forecast the *distribution* of the sum of contributions of his teammates *and* the distributions of each rival team's total effort.[10] In contrast, the private-information best-shot model is tractable, requiring only the analysis of an order statistic.[11] Furthermore, the best-shot performance seems a better description than summation for some group contest situations, such as those involving a competition of "great ideas" (see, e.g., Morgan and Wang, 2010, p. 79; Levitt, 1995, p. 744). Building design competitions are just such an example.

To our knowledge, the only other study of group contests with private information is by Brookins and Ryvkin (2015), who take a different tack. Unlike their approach, ours admits closed-form equilibrium strategies (see ft. 10). Also closely related to the current paper is the perfect-information model of Barbieri et al. (2014), which also models group contests as best-shot all-pay auctions.[12] Barbieri et al. (2014) show that an increase in team size leads, in the symmetric equilibrium, to lower individual and group efforts and greater payoffs. Thus, as teams symmetrically increase in size, incentives to free-ride

[2] See, for example, Hillman and Riley (1989) and Baye et al. (1996).

[3] See, for example, Nitzan (1991a, 1991b), Lee (1995), Katz and Tokatlidu (1996), Wärneryd (1998), Münster (2007), and Choi et al. (2013).

[4] See, for example, Katz et al. (1990), Baik (1993, 2008), Baik et al. (2001), Barbieri et al. (2014), Chowdhury et al. (2013), and Kolmar and Rommeswinkel (2013).

[5] The papers cited in ft. 4 provide further examples.

[6] Konrad (2009) surveys issues of designing group contests with full information.

[7] Our framework readily accommodates a prize for the "overall" winning player, over and above the team's, as long as the prize size does not depend on efforts.

[8] Hirshleifer (1983) proposed several possibilities for aggregating group efforts: the best shot (equal to the maximum effort), the weakest link (equal to the minimum effort), and the summation. With full information, Kolmar and Rommeswinkel (2013) use a generalized group aggregation that allows for different degrees of complementarity among members' efforts in each group, covering the gamut from the weakest link to the summation, but not from summation to the best shot.

[9] The classic reference here is Bergstrom et al. (1986).

[10] Brookins and Ryvkin (2015) study an imperfectly discriminating contest among symmetric groups where players' costs of effort are private information and each team's effective effort equals the sum of its members' efforts. They establish existence of a symmetric equilibrium under quite general conditions. Assuming a lottery csf, they depict equilibrium strategies using numerical techniques.

[11] This simplification is also key to the analysis of private contributions to public goods in Barbieri and Malueg (2014a).

[12] However, in that paper, all members on a team have the same value for winning and equilibrium is in mixed strategies.

Two other perfect-information public-good models of group contests should be mentioned. Chowdhury et al. (2013) suppose a group's performance is given by the team's best shot, and the winning team is determined by a lottery csf taking as inputs each team's best shot. Baik et al. (2001) suppose each team's performance equals the sum of members' efforts and the winning team is the one with the largest total effort (thus, an all-pay auction). These authors find that in equilibrium only one player on a team exerts effort (for Baik et al. it is necessarily the player with the greatest value). Thus, these frameworks are not especially conducive to examining the role of team size or the number of teams in the competition.