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Contests with group size uncertainty: Experimental evidence

Luke Boosey [a,*], Philip Brookins [b], Dmitry Ryvkin [a]

[a] Department of Economics, Florida State University, Tallahassee, FL 32306-2180, USA
[b] Max Planck Institute for Research on Collective Goods, Kurt-Schumacher-Str. 10, D-53113, Bonn, Germany

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ABSTRACT

In many contest situations, the number of participants is not observable at the time of investment. We design a laboratory experiment to study individual behavior in Tullock (lottery) contests with group size uncertainty. There is a fixed pool of n potential players, each with independent probability $q \in (0, 1]$ of participating. We independently manipulate each of the parameters and test the implied comparative statics predictions. Our results provide considerable support for the theory, both in terms of comparative statics and point predictions. Most surprisingly, we find no evidence of overbidding in treatments where there is a nontrivial probability that group size is one. This stands in stark contrast to the robust overbidding observed in experimental contests with deterministic group size. We propose a one-parameter model that incorporates nonlinear probability weighting and a modified version of joy of winning, which we call *Constant Winning Aspirations* (CWA), and show that it neatly organizes all of our results.

1. Introduction

In contests, such as R&D races, political campaigns, lobbying, litigation, or job market tournaments, participants spend resources to secure a valuable prize.[1] While in most contest models it is assumed that the number of contestants is common knowledge, it is often the case that at the time a contestant has to choose her investment, she is not aware of how many other competitors she will face. Thus, in modeling the behavior of agents involved in contests, group size uncertainty can be both an appealing and realistic feature.

There are, in general, two ways to think about the emergence of uncertainty about the number of contestants. On the one hand, entry into contests may be endogenous, with each potential contestant deciding simultaneously, and privately, whether or not to participate. Typically, a model with endogenous entry will have a symmetric equilibrium in mixed strategies, which induces uncertainty about the realized size of the group. The equilibrium entry probability, q^*, can be manipulated exogenously by varying the parameters of the environment, such as the value of the prize, outside option or entry fee. Changes in q^* induced in this manner will in turn lead to changes in the equilibrium contest investment. Thus, one might think of the underlying group size uncertainty as being driven by the decisions of a third party, such as a contest

* Corresponding author.
E-mail addresses: lboosey@fsu.edu (L. Boosey), brookins@coll.mpg.de (P. Brookins), dryvkin@fsu.edu (D. Ryvkin).

[1] For a recent survey of the theoretical literature on contests, see, e.g., Konrad (2009), Congleton et al. (2008), Corchón (2007), Connelly et al. (2014); for a summary of some nonexperimental empirical results in personnel economics and sports, see, e.g., Prendergast (1999) and Szymanski (2003); for a survey of the experimental literature on contests, see Dechenaux et al. (2015).

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organizer, industry regulator, or governing body. For example, an R&D firm may only be able to participate in a contest if particular quality control or safety protocols are satisfied, regulatory barriers are removed, or certain legislation is passed.[2] In these settings, it is important to understand how the resulting contest investment changes in response to a change in external parameters (e.g., regulation), which requires one to understand the comparative statics of equilibrium investment with respect to q^*.

On the other hand, a somewhat simpler and more direct approach is to bypass the entry decision entirely and assume that group size uncertainty is exogenous. One possibility is to assume, as in Lim and Matros (2009), that there is a fixed number n of potential contestants and, from the perspective of an active contest participant, the number of other active participants is distributed as Binomial$(n-1, q)$, with some underlying probability of participation q. By studying the comparative statics of equilibrium investment with respect to q and n, one can gain valuable insight into the effects of group size uncertainty in contests in isolation from the entry decision. Indeed, in any symmetric equilibrium of a model with entry, an active participant forms beliefs about others' participation probability and consequently about the distribution of actual contest size. In a setting with exogenous group size uncertainty, these beliefs can be manipulated directly, but the resulting comparative statics are essential in understanding the effects of external factors in an environment with endogenous entry as well.

In this paper, we use a laboratory experiment to study the behavior of individuals in a contest with group size uncertainty. In particular, we test two theoretical predictions about individual equilibrium investment derived by Lim and Matros (2009) for Tullock (1980) lottery contests with a stochastic number of players following the binomial distribution with parameters (n, q). There is a unique symmetric equilibrium that exhibits two key features. First, for any fixed number of potential players $n > 2$, individual equilibrium investment is single-peaked in the probability of participation q. Second, for any two values of n, the individual equilibrium investment functions satisfy a single-crossing property; as a result, for different values of q, increasing the number of potential players can have opposite effects on individual investment. The intuition for this reversal is as follows. When q is small and n is low, the modal group size is one (i.e., a player in a group by herself) and the equilibrium investment is very low. As n increases, group sizes larger than one become more likely and the equilibrium investment goes up. In contrast, when q is large, the group size is almost certainly greater than one, and hence an increase in n has the same effect on individual equilibrium investment as in standard contests where the number of players is known, i.e., the investment goes down.

In our experiment, we use a 2×2 between- and within-subject hybrid design to test these comparative statics. In the resulting four treatments, we independently manipulate the maximal number of bidders ($n = 3$ and $n = 6$) and the participation probability ($q = 0.2$ and $q = 0.8$). The parameters are selected so that individual equilibrium investment is increasing in n for the low value of q and decreasing in n for the high value of q. As a robustness check, we also vary the participation probability within subjects for each n, accounting for possible order effects.

We make three key contributions in this paper. First, to the best of our knowledge, this is the first experimental study to explore the comparative statics of behavior in contests with group size uncertainty. There is a well-developed theoretical literature on contests with a stochastic number of participants (Münster, 2006; Myerson and Wärneryd, 2006; Lim and Matros, 2009; Fu et al., 2011; Kahana and Klunover, 2015, 2016; Ryvkin and Drugov, 2017), including contests with endogenous entry (Fu and Lu, 2010). Our study is also related to that of Morgan et al. (2012), who explored endogenous entry in contests experimentally. However, Morgan et al. (2012) model entry as a sequential process, and there is no group size uncertainty at the time when subjects make their investment decisions. Games with population uncertainty have also been studied in other environments, including auctions,[3] as well as voting, public goods, and coordination game settings modeled as Poisson games.[4]

The second key contribution of our study is methodological. Specifically, our experimental design has two important novel features. The first is that instead of informing subjects about the underlying participation probability, q, we inform them directly about the probabilities, q_m, of different realizations of random group size $m \in \{1, \dots, n\}$. We do this for a couple of reasons. On the one hand, we believe this information is easier for subjects to understand. On the other hand, and arguably more importantly, we feel that this approach is also more "ecologically valid," in the sense that people in the field are more likely to think about situations with population uncertainty in terms of probabilities of possible outcomes (group sizes) as opposed to the underlying stochastic process (which may be unknown). In this respect, our results are not dependent on subjects' abilities to correctly calculate binomial outcome probabilities, nor do they depend on the precise underlying stochastic process used to generate these probabilities. The second novel feature of our design is that, even though subjects participate in games with random group sizes, we draw the relevant groups and determine the probability of winning independently for each subject. This approach allows us to maximize the number of observations and avoid

[2] We are grateful to an anonymous referee for suggesting regulation as a source of exogenous variation in the participation probability. In addition to R&D competition, other examples of contest environments where entry probability, and hence the underlying group size uncertainty, may be manipulated by third parties include lobbyists competing in a rent-seeking contest or job candidates applying for a promotion or new position.

[3] For a theoretical analysis of auctions with a stochastic number of bidders see, e.g., McAfee and McMillan (1987), Harstad et al. (1990) and Levin and Ozdenoren (2004). For a theoretical analysis of endogenous entry in auctions see, e.g., Levin and Smith (1994) and Pevnitskaya (2004). Experiments on auctions with a stochastic number of bidders and endogenous entry include Dyer et al. (1989), Isaac et al. (2012) and Palfrey and Pevnitskaya (2008).

[4] See, e.g., Myerson (1998, 2000); Makris (2008, 2009); De Sinopoli and Pimienta (2009); Mohlin et al. (2015); Ioannou and Makris (2017).