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The optimal disclosure policy in contests with stochastic entry: A Bayesian persuasion perspective

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HIGHLIGHTS

- We study effort-maximizing disclosure policy of the number of entrants in contests.
- We adopt a setting of imperfectly discriminatory contests with stochastic entry.
- We follow a Bayesian persuasion approach.
- For concave characteristic functions, full disclosure is optimal.
- For convex characteristic functions, full concealment is optimal.

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ABSTRACT

Following a Bayesian persuasion approach, we establish that full disclosure (resp. concealment) is the contest organizer's effort-maximizing policy for disclosing the number of actual contestants if the characteristic function of the imperfectly discriminatory contest technology is strictly concave (resp. convex).

1. Introduction

Stochastic entry is abundant in real-life contests. Crowdsourcing contests exhibit great uncertainty about the number of participants. In a typical labor-market phenomenon, a random number of job applicants compete for the same post. In procurement tournaments, the number of interested suppliers is rarely perfectly predictable.

With stochastic entry, both the organizer and the players are uncertain about the number of entrants *ex ante*, however, the contest organizer often has *ex post* superior information about the number of entrants. The contest organizer might observe the number of actual participants after receiving contestants' entries, while the entrants usually do not have access to that information. This ex post information asymmetry between the organizer and the entrants creates room for the organizer to pre-commit to an ex post information disclosure policy to influence the entrants' effort supply by manipulating their posterior beliefs about the number of participants.

We consider an imperfectly discriminatory contest in which players are randomly selected by nature as participants. All entrants compete for a single prize. To maximize the expected participants' aggregate effort, the organizer pre-commits a public disclosure policy to control how much information to reveal about the number of actual contestants. Following Bayesian persuasion approach, we model the disclosure policy as a contingent signal-generating mechanism. Applying the Bayesian persuasion approach requires that the organizer commits on her choice of disclosure policy. The contest organizers often have this commitment power in many real contest situations. It is typically the case that

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the contest rules including the disclosure policy are announced publicly ex ante, and the organizers would follow the committed rule to maintain their authority. In particular, in many online contests, the disclosure policy is pre-committed by the design of the hosting web-pages. Ex post deviations are usually infeasible.

To determine the optimal disclosure policy, one key step is to understand how a signal realization affects entrants' effort supply through their posterior belief under a given policy. In addition to the public signal released by the organizer, an entrant will also observe his own entry status. Thus, an entrant must update his own belief by combining these two sources of information. Moreover, the identity of an entrant can influence his belief updating so that a public signal may lead to different posterior beliefs across entrants. To avoid this complication, we impose a "symmetry" assumption on the entry process, which renders common posteriors across all entrants.

Our paper is closely related to two strands of literature. First, it belongs to the literature on information disclosure policy about number of entrants in auctions and contests. McAfee and McMillan (1987) compare full-disclosure and no-disclosure policies in a first-price sealed-bid auction setting with risk-averse bidders, and find that the seller always prefers full concealment policy. Lim and Matros (2009) establish that the organizer is indifferent between full-revealing and full-concealing policies in a Tullock contest setting. Fu et al. (2011) further compare full-revealing and full-concealing policies in contest settings with more general contest technology. Our paper differentiates from these studies by searching for the optimal disclosure policy within a much broader scope of eligible policies.

Our analysis is inspired by some recent studies in the Bayesian persuasion approach. Kamenica and Gentzkow (2011) introduce Bayesian persuasion to study how a sender manipulates a receiver's belief in a way favored by the sender. They formulate the problem in terms of the distribution of posteriors and develop a concavification technique to solve for the optimal method of persuasion. Wang (2012) and Chan et al. (2015) study persuasions in the voting games with multiple receivers. Li and Norman (2015) consider a class of multi-sender persuasion games that accommodate both sequential and simultaneous moves. Zhang and Zhou (forthcoming) apply the Bayesian persuasion approach to study how to influence an uninformed contestant's belief about his opponent's private valuation in a contest. Ely et al. (2015) further study how to reveal information over time to maximize expected suspense and surprise. Our paper demonstrates another application of the Bayesian persuasion approach in a contest environment with multiple receivers. A unique feature of our problem lies in that each entrant (receiver) forms his own posterior belief based on both the public information released by the organizer and additional information about his own entry status.

2. The model setup

We consider an imperfectly discriminatory contest with a single prize v. There are M potential contestants and one contest organizer. It is common knowledge among the potential contestants and the organizer that a subset $A \in 2^M$ has probability $\mu_0(A)$ participating in the contest, with $\sum_{A\in 2^M} \mu_0(A) = 1$. After the participating group has been selected, the organizer observes the number of participants, and every player only observes his own participation status.

Suppose that a non-empty set $A \in 2^M$ is selected as participants, then $\forall i \in A$, his winning probability is given by

$$p_i(x_i, \mathbf{x}_{A\setminus\{i\}}) = \frac{f(x_i)}{\sum_{j\in A} f(x_j)},$$

where $f(\cdot)$ is called the impact function, x_i denotes the effort of entrant i, and $\mathbf{x}_{A\setminus\{i\}}$ denotes the effort of other entrants in A.[1]

The contest organizer aims to maximize participants' effort supply by choosing a pre-committed disclosure policy before nature selects the participating group.[2] Let $S = \Omega = \{0, 1, 2, \ldots, M\}$. The organizer commits to a disclosure policy denoted by $\{\pi(\cdot|N)\}_{N\in\Omega}$ over the signal space S. After observing the realized N, the organizer publicly releases a signal $s \in S$ with probability $\pi(\cdot|N)$. An entrant i observes the signal realization s and his own entry status to form his posterior belief $\mu(\cdot|s, i)$ over the numbers of entrants.[3]

3. The analysis on optimal disclosure policy

In Section 3.1, we adopt an "symmetry" assumption and identify the entrants' common posterior belief conditional on his own entry and a public signal generated by a disclosure policy. In Section 3.2, we analyze their equilibrium behavior. Combining the results, we formalize the organizer's problem and solve for the optimal disclosure policy in Section 3.3.

3.1. Belief updating

Given that agent i is selected as an entrant, conditional on s, his posterior belief $\mu(A|s, i)$ about $A \in 2^M$ is as follows: $\mu(A|s, i) = 0$, $\forall i \notin A$; and $\mu(A_i|s, i) = \frac{\pi(s|\ |A_i|)\mu_0(A_i)}{\sum_{\forall A_i\in 2^M} \pi(s|\ |A_i|)\mu_0(A_i)}$, $\forall A_i$. To avoid identity-contingent belief-updating process, we impose the following "symmetry" assumption.

Assumption 1 (*Symmetry in Entry*). If $|A| = |A'|$, we have $\mu_0(A) = \mu_0(A')$.

Assumption 1 says that any two groups with the same size have the same participating probability, which means that what will affect the participating probability of a group is the size of the group, instead of the contestants' identities in that group. In particular, it accommodates the case in which each contestant has a fixed and independent participating probability. Under Assumption 1, we can then focus on the contestants' belief about the number of entrants. In the following proposition, we establish the connection between an entrant's posterior belief $\mu(N|s, i)$ and the signal realization s.

Proposition 1. *Under Assumption 1, contingent on signal realization s and observing his own entry, every entrant holds the following common posterior belief*

$$\mu(N|s, e) = \frac{N\mu_s(N)}{\sum_{N'=1}^{M} N'\mu_s(N')}, \quad \forall N \in \{0, 1, \ldots, M\}, \tag{1}$$

where $\mu_s(N) = \frac{\pi(s|N)\mu_0(N)}{\sum_{N'=0}^{M} \pi(s|N')\mu_0(N')}$, $\forall N \in \{0, 1, \ldots, M\}$ *denotes a contestant's updated belief based only on the signal realization s, without knowing his own entry status.*

[1] Each entrant exerts non-negative effort.

[2] We assume that the organizer has precommitment power to stick to this disclosure policy.

[3] According to Kamenica and Gentzkow (2011) and Zhang and Zhou (forthcoming), it is without loss of generality to consider the above signal space $S = \Omega$ for the optimal disclosure policy.