Races or Tournaments? [Draft: Please do not distribute][1]

Andrea Blasco Kevin J. Boudreau Karim R. Lakhani
Michael Menietti

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[1]Blasco: Harvard Institute for Quantitative Social Science, Harvard University, 1737 Cambridge Street, Cambridge, MA 02138 (email: ablasco@fas.harvard.edu)

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Abstract

A wide range of economic and social situations are decided by either a race or a tournament. In such contests, agents choose whether and how much to exert some costly effort to increase the probability of being awarded a prize under uncertainty about the other agents types or actions. In theory, whenever the sponsor of the competition prefers competitors' performance over the time to complete a particular task, the expected outcomes of a tournament setup should be either equal or greater than those of a race. Yet, a race might be more efficient from an economic point of view as it may prevent unnecessary costs due to an excess of participation. We examine this trade-off empirically. We report the results of a field experiment conducted on a leading crowdsourcing platform where we compare the outcomes (efforts, quality, and diversity of outputs) of three alternative competitive situations motivated by theory: the race, the tournament, and the tournament with a quality requirement.

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1 Introduction

Contests are a very important source of incentives in the economy. In the US, the government regularly sponsors open competitions in order to solve challenging problems of public health, education, energy, environmental issues, and so on.[1] In the private sector, firms use contests to rapidly expand their innovative ability (conducting open innovation initiatives) and, internally, as a means to motivate workers (bonuses, pay increases, promotions). So, understanding how to effectively design a contest to best achieve the desired goals is an important economic issue.

The purpose of this study is to better understand the difference between two quite popular choices of contest design: the race (a competition to be first) and the tournament (a competition to be best). In particular, we try to address the following research questions: How this choice affect contestants? When the sponsor of a competition should pick one or the other? What is the main trade-off? How this decision interact with other key choices of design such as the distribution of prizes among winners?

To address these questions we proceed in two ways. First, we generalize the incomplete-information contest model of Moldovanu and Sela (2001) to allow for a comparison of both the race and the tournament within a single framework. Then, we gather experimental data in the field from expert competitors engaged in an online programming competition, which we use to test some of the implications of the theory.

Economists have a long tradition in studying races, of various kinds (patent races or arms races), and tournaments. A large body of works have investigated several aspects of contest design, including xxx, xxx, xxxx. However, they rarely consider the race as the result of a deliberate choice of contest design. So we do not have many results on when and why to use a race instead of a tournament. On the other hand, there is a wide literature

[1] On a monthly basis, the web portal www.challenge.gov publishes calls for new online challenges seeking problem solvers from all around the world.

on tournaments and in particular we have many investigations on the optimal design of a tournament. These works seem to suggest that tournaments act as incentive mechanisms to maximize expected total or average effort of competitors.

By this perspective, we are able to show that races cannot be justified simply by the goal of maximizing average effort. And the reason is intuitive. A race awards a prize to first to hit a particular target. Those who will judge the target to hard to achieve will not join the competition and will drop out. On the contrary, those who are able to achieve the target at low costs will not try to exceed the target. As a result, the race is comparable to a competition with fixed "entry costs" or a fixed entry requirement, where agents will decide to either enter and pay a fixed prize, or stay out of the competition. Then, the possible gains in terms of expected revenues from a race are limited to those who would enter the competition and would exert less effort that that required to hit the target. These potential benefits can be obtained under a tournament as well by imposing a a fixed requirement to be eligible for prizes. So, races are not chosen to maximize expected effort of competitors, at least, in the traditional "auction-theoretical" sense.

What are races for? We examine a few hypothesis and we provide some examples. First hypothesis is that the sponsor of the race is not primarily interested in total output but also in the time to complete a particular task. In a tournament, this type of preferences can be satisfied by fixing a deadline. Say time within which competitors are asked to provide their efforts. However, assuming competitors have costs from making less time in performing a task and there complementarities in costs, increasing the deadline in a tournament is similar to raising the marginal cost for everyone, which might not be an optimal solution. In a race, by contrast, increasing the deadline will affect entry but, conditional on entry, the time to complete the task will always be less than the deadline. Which means that those with low costs will be mostly affected by the deadline, whereas xxxx. Which may be a superior choice than the tournament.

To fix ideas let consider the following example. The government wants to solve a global public health problem such as “antibiotics resistance.” The overuse of antibiotics leads to the phenomenon of “resistance” which is a loss in the power of antibiotics to treat certain infections. This is an increasing threat for public health. The government has the choice of making a contest to engage people in solving this problem. The government has preferences for time in the sense that the government wants to minimize to have the first submission. So, the government fix a requirement in terms of costs of the solution and award a prize to the first to meet this requirement. Example. UK governemet goes for a race. EU xxxx goes for a tournament with a deadline in 2016. (. . .) The answer to this optimal design question relates to the cost function of agents with respect to “time” and to “effort.” It is hard to say which solution is better. However, it is easier to tell whether you should have one prize or multiple prizes.

There is also a case for efficiency. Consider a platform with many competitions. The platform may want to engage competitors for short period of time provide that solutions are above a certain quality level.

To test our theory we further examine experimental data on competitors making sumibssion in an online computer programming contest. We randomized competitors into 3 groups: 1. race 2. tournament 3. tournament with a quality requirement we study participation, timing of submission and final scores.

We find that, as our theory suggest, participation is higher in the tournament and lower in the race and in the tournament with entry costs. We further find that submission are quicker in a race, whereas are equally distributed at the end of the competition in the the tournament and in the tournament with quality requirement. With respect to final scores, theory predicts as trade-off between a race and a tournament in terms of higher scores vs faster submissions. We do find that scores are higher in the tournament but we do not find a strong trade-off in the sense that race had comparable good quality solutions than the tournament.

2 Literature

This paper is related to the contest theory literature Dixit (1987) Baye and Hoppe (2003), Parreiras and Rubinchik (2010), Moldovanu and Sela (2001), Moldovanu and Sela (2006), Siegel (2009), Siegel (2014). It also relates to the literature on innovation contests Taylor (1995), Che and Gale (2003). And the personnel economics approach to contests Lazear and Rosen (1981), Green and Stokey (1983), Mary et al. (1984).

Empirically, Dechenaux et al. (2014) provide a comprehensive summary of the experimental literature on contests and tourments. Large body of empirical works have focused on sports contests Szymanski (2003). More recently, inside firms (xxx) and online contest (xxxx).

This paper is also related to the econometrics of auctions Paarsch (1992), Laffont et al. (1995), Donald and Paarsch (1996) and more recently Athey et al. (2011), Athey and Haile (2002), and Athey and Haile (2007).

3 Races and tournaments

3.1 The basic theoretical model

Consider a contest with k available prizes of value $V_1 > V_2 > ... > V_k$. Each agent $(i = 1, ..., n+1)$ moves simultaneously to maximize the chances of winning a prize. To be elegible for a prize, each agent has to complete a task within a deadline $d > 0$. Outcomes are then evaluated and ranked along two dimensions: the output quality y_i and the time to completion t_i both being nonnegative real numbers.

In a tournament, the agent having achieved the highest output quality within the deadline gets the first prize, the agent having achieved the second highest output quality gets the second prize, and so on. In a race, by contrast, the first agent to achieve an output quality of at least $\bar{y}$ within the deadline wins the first prize, the second to achieve the same target gets the second prize, and so on.

Since agents move simultaneously, they do not know the performance of others when deciding their efforts. On the other hand, it is assumed that they know the number of competitors as well as their cost functions to complete the task up to a factor a_i being the agent's private ability in performing the task. Each agent knows his ability but does not know the ability of the others. However, it is common knowledge that abilities are drawn at random from a common distribution F_A that is assumed everywhere differentiable on the support $V \subseteq [0, \infty)$.

It is further assumed that costs are multiplicative

$$C(y_i, t_i, a_i) = c_y(y) \cdot c_t(t) \cdot a_i^{-1} \tag{1}$$

with $c_y(0) \geq 0$, $c_y' > 0$, $c_t(d) \geq 0$, and $c_t' < 0$.

Each agent is risk neutral and faces the following decision problem

$$\text{maximize} \quad \textstyle\sum_{j=1}^{k} \Pr(\text{ranked } j\text{'th}) V_j - C(y_i, t_i, a_i). \tag{2}$$

3.1.1 Equilibrium in a tournament

We provide here the symmetric equilibrium with one prize [todo: two prizes] and $n > 2$ agents. In appendix XXX, we provide a general formula for $k > 2$ prizes.

Let $y_{1:n} < y_{2:n} < ... < y_{n:n}$ denote the order statistics of the y_j's for every $j \neq i$ and let $F_{Y_{r:n}}(\cdot)$ and $f_{Y_{r:n}}(\cdot)$ denote the corresponding distribution and density for the r'th order statistic.

In a tournament, the unique symmetric equilibrium of the model gives, for every $i = 1, ..., n$, the optimal time to completion $t^*(a_i)$ equal to the deadline d and the optimal output quality $y^*(a_i)$ as

$$y^*(a_i) = V_1 \int_{a_i}^{\infty} f_{Y_{n:n}}(z)dz \tag{3}$$

if $a_i \geq \underline{a}$ (see Moldovanu and Sela, 2001), and equal to zero otherwise.

An important property of (3) is that $y^*(a_i)$ has its upper bound in [value] and lower bound in [value]. Also, equilibrium output quality is monotonic increasing in the agent's ability (see Moldovanu and Sela, 2001). Thus, for every $i = 1, ..., n + 1$, the equilibrium expected reward depends only on the rank of his ability relative to the others. Using $F_{A_{r:n}}$ to denote the distribution of the r'th order statistic of abilities gives

$$F_{A_{n:n}}(a_i)V_1 - C(y_i^*, d, a_i). \tag{4}$$

Hence, by setting (4) to zero and solving for the ability, gives the marginal ability $\underline{a}$ as

$$\underline{a} = h(n, V, F_A, C, d). \tag{5}$$

3.1.2 Equilibrium behavior in a race

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3.1.3 The expected revenues for the sponsor of the contest

The sponsor of the contest chooses the rules of the competition including prize structure $\{V_j\}_{j=1}^k$, deadline d, target quality q, and competition format (race or tournament). The sponsor maximizes an objective function that is the sum of total quality $Y = \sum_{i=1}^{n+1} Y_i$, time spent $T = \sum_{i=1}^{n+1} T_i$ and prizes paid $V = \sum_{j=1}^{k} p_j V_j$ (with $p_j = 1$ if the prize is awarded and $p_j = 0$ otherwise). Hence, the problem faced by the sponsor is

$$\text{maximize} \quad \int Y - \tau \mathbf{E}T - \mathbf{E}V \tag{6}$$

with the intensity of preferences towards time weighted by $c_t \geq 0$.

3.2 Structural econometric model

4 A comparison of races and tournaments in the field

In this section, we illustrate the preceding econometric methods by an empirical analysis of the outcomes of a field experiment that was conducted to compare races and tournaments in the field of online programming competitions.[2]

4.1 The context

The study was conducted on the online platform Topcoder.com from March 8 to March 16, 2016. Since its launch in 2010, Topcoder.com hosts on a weekly basis competitive programming contests for thousands of competitors from all over the world. All Topcoder members — about 1M registered users in 2016 — can compete and attain a "rating" that provides a metric of their ability as a competitor. Participation is free but limited to people over 18 years old. Typical assigned problems are data science problems that involve some background in machine learning and statistics to be solved (see XXX for a few examples). Other than attaining a rating, the competitors having made the top five submissions usually win a monetary prize. And awards can range considerably depending on the nature and complexity of the problem and generally between \$5,000 to \$20,000.

The assigned problem: In this study, we worked together with researchers from the National Health Institute (NIH) and the Scripps Research Institute to select a challenging problem for an experimental programming

[2] A competitive programming contest is a competition that involves participants writing source code for an executable computer program to solve a given problem.

competition. The problem was based on an algorithm built by NIH that uses expert labeling to annotate abstracts from PubMed — a prominent life sciences and biomedical search engine — so disease characteristics can be more easily identified. This open-source, supervised learning system called BANNER achieves a good level of prediction power [see xxx]. The goal of the challenge was to improve upon the current NIH's system.

Groups: Signed up competitors were randomly assigned to separate groups under three different competitive settings: a race, a tournament, and a tournament with a minimum quality requirement. Each group had access to a personalized webpage showing a leaderboard showing periodic updates on the submissions of the other competitors of the group.

Payoffs: In each room, the first placed competitor was awarded a prize of $1000 (an additional consolatory prize of $100 was awarded to the second placed). Every competitor had to solve the same exact programming problem: it In a race, xxxx. In a tournament, xxxx .And in a tournament with minimum quality requirement, xxxx.

Surveys: Additional information, such as demographics, all registered competitors had to fill out online an initial and final survey before and after the competition. In the initial survey, they were asked basic demographics, including a measure of risk aversion. They were also asked to forecast the number of hours they would be able to spend competing in the next few days. The exact question was: "looking ahead xxxx". In the final survey, we asked them to look back and tell us their best estimate of the time spent working on the problem.

We also gathered public data from their online web profile on the platform. This includes a number of statistics about a coder's past performance on the platoform. We focused on three main measures: the date in which the member registered, the number of achievements (also called "badges"), whether they participated in any similar competition in the past. The date is simply to capture personal experience with the platform. Badges are given for a variety of reasons ranging from simple tasks, such as first post on the forum, to more complex achievements, such as winning 5 competitions or more. The majority of goals are for complex achievement, thus having a high number of achievements can be regarded as a good measure of high skills.

4.2 Data

A total of 299 competitors signed up for the challenge. All were registered members of the platform (the competitor's median time as member of the platform was of 5 years). Individual experience in competing was highly skewed, with competitors in the 90th percentile having taken part in 28 more competitions and with a skill rating, if any, of 999 higher rating points than those in the 10th percentile; see Figure 1.

[Figure 1 about here.]

5 Empirical analysis

5.1 Estimation results

Participation to the competition by treatment is shown in Figure **??**. Participation here is measured by the proportion of registered participants per treatment who made any submission during the eight-day submission period. Recall that competitors may decide to enter into the competition and work on the problem without necessarily submitting. In a tournament, for example, competitors are awarded a prize based on their last submission and may decide to drop out without submitting anything. However, this scenario seems unlikely. In fact, competitors often end up making multiple submissions because by doing so they obtain intermediate feedback via preliminary scoring (see Section XXX for details). In a race, competitors have even stronger incentives to make early submissions as any submission that hits the target first wins.

`Table xxx`

We find that the propensity to make a submission is higher in the Tournament than in the Race and in the Tournament with reserve, but the difference is not statistically significant (a Fisher's exact test gives a p-value of `r round(fisher.test(nsub.tab)$p.val,3)`). As discussed in Section XXX, we may not have enough power to detect differences below 5 percentage points. However, we find the same not-significant result in a parametric regression analysis of treatment differences with controls for the demographics and past experience on the platform; see Table **??**. Adding individual covariates reduces variability of outcomes, potentially increasing the power of our test. In particular, Table **??** reports the results from a logistic regression on the probability of making a submissions. Column 1 reports the results from a baseline model with only treatment dummies. Column 2 adds demographics controls, such as the age, education, and gender. Column 3 adds controls for the past experience on the platform. Across all these specifications, the impact of the treatment dummies (including room size) on entry is not statistically significant.

5.2 Simulation results

References

Athey, Susan and Philip A Haile, "Identification of standard auction models," *Econometrica*, 2002, *70* (6), 2107–2140.

_ and _ , "Nonparametric approaches to auctions," *Handbook of econometrics*, 2007, *6*, 3847–3965.

_ , Jonathan Levin, and Enrique Seira, "Comparing open and Sealed Bid Auctions: Evidence from Timber Auctions*," *The Quarterly Journal of Economics*, 2011, *126* (1), 207–257.

Baye, Michael R and Heidrun C Hoppe, "The strategic equivalence of rent-seeking, innovation, and patent-race games," *Games and Economic Behavior*, 2003, *44* (2), 217–226.

Che, Yeon-Koo and Ian Gale, "Optimal design of research contests," *The American Economic Review*, 2003, *93* (3), 646–671.

Dechenaux, Emmanuel, Dan Kovenock, and Roman M Sheremeta, "A survey of experimental research on contests, all-pay auctions and tournaments," *Experimental Economics*, 2014, pp. 1–61.

Dixit, Avinash Kamalakar, "Strategic Behavior in Contests," *The American Economic Review*, 1987, *77* (5), 891–98.

Donald, Stephen G and Harry J Paarsch, "Identification, estimation, and testing in parametric empirical models of auctions within the independent private values paradigm," *Econometric Theory*, 1996, *12* (03), 517–567.

Green, Jerry R and Nancy L Stokey, "A Comparison of Tournaments and Contracts," *The Journal of Political Economy*, 1983, *91* (3), 349–364.

Laffont, Jean-Jacques, Herve Ossard, and Quang Vuong, "Econometrics of First-Price Auctions," *Econometrica*, 1995, *63* (4), 953–80.

Lazear, Edward P and Sherwin Rosen, "Rank-Order Tournaments as Optimum Labor Contracts," *The Journal of Political Economy*, 1981, *89* (5), 841–864.

Mary, O'Keeffe, W Kip Viscusi, and Richard J Zeckhauser, "Economic Contests: Comparative Reward Schemes," *Journal of Labor Economics*, 1984, *2* (1), 27–56.

Moldovanu, Benny and Aner Sela, "The optimal allocation of prizes in contests," *The American Economic Review*, 2001, pp. 542–558.

_ **and** _ , "Contest architecture," *Journal of Economic Theory*, 2006, *126* (1), 70–96.

Paarsch, Harry J, "Deciding between the common and private value paradigms in empirical models of auctions," *Journal of econometrics*, 1992, *51* (1-2), 191–215.

Parreiras, Sérgio O and Anna Rubinchik, "Contests with three or more heterogeneous agents," *Games and Economic Behavior*, 2010, *68* (2), 703–715.

Siegel, Ron, "All-Pay Contests," *Econometrica*, 2009, *77* (1), 71–92.

_ , "Contests with productive effort," *International Journal of Game Theory*, 2014, *43* (3), 515–523.

Szymanski, Stefan, "The Economic Design of Sporting Contests," *Journal of Economic Literature*, 2003, *41* (4), 1137–1187.

Taylor, Curtis R, "Digging for Golden Carrots: An Analysis of Research Tournaments," *The American Economic Review*, 1995, *85* (4), 872–90.

List of Figures

Figure 1: Distribution of the count of past contests (left panel) and the skill ratings (right panel) of the signed-up competitors.