Teamwork in Contests

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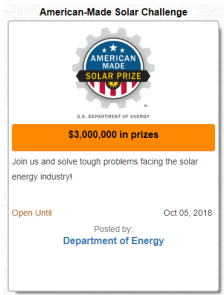
Motivation

Open contests increasingly used as a mechanism to solve problems



US Government: challenge.gov

kaggle
HackerRank
INNOCENTIVE
TUNEDIT
topcoder

Online platforms

Motivation

- In practice, many of these contests are *dynamic* and feature *public* information disclosure.
  - Players can make multiple submissions over time.
  - Players often observe a real-time leaderboard.

- These contests often allow players to *collaborate*.
  - Player can choose to compete as *solo* players or *self-organize teams*.

- These (and other) features have motivated empirical and theoretical work studying optimal contest design.

Research question

- Should online contest platforms allow self-organized teams?
  - Platform's goal: maximize some contest outcome
  - Contest theory suggests that aggregate effort tends to *increase* with the number of players
  - Teamwork:
    $\rightarrow$ Reduces the number of players
    $\rightarrow$ Can create synergies or productivity gains
    $\rightarrow$ Solo players may get discouraged from facing stronger rivals

- Teamwork creates a quality vs competition tradeoff.

Goals of the paper

- Do members of self-organize teams enhance their performance?
- Investigate dynamic incentives to form teams
- Equilibrium framework to evaluate the impacts of teamwork

Setting

Kaggle.com

- Popular class of online contests: *prediction contests*

Contests hosted by Kaggle

Data Science Bowl 2017
Can you improve lung cancer detection?
Featured · 2 months to go · 585 kernels
$1,000,000
1,237 teams

The Nature Conservancy Fisheries Monitoring
Can you detect and classify species of fish?
Featured · 2 months to go · 282 kernels
$150,000
1,619 teams

Google Cloud & YouTube-8M Video Understanding Challenge
Can you produce the best video tag predictions?
Featured · 3 months to go · 42 kernels
$100,000
149 teams

Dstl Satellite Imagery Feature Detection
Can you train an eye in the sky?
Featured · 9 days to go · 152 kernels
$100,000
339 teams

Two Sigma Financial Modeling Challenge
Can you uncover predictive value in an uncertain world?
Featured · 3 days to go · 212 kernels
$100,000
2,046 teams

How Kaggle contests work

- Goal: Procure a prediction algorithm
  - E.g., predict video tags for YouTube videos
- Participants access data to train their algorithms
- Participants can submit multiple entries during the contest
- Submissions are scored based on their out-of-sample performance (e.g., RMSE) on two samples:
  - Sample 1: Public score
  - Sample 2: Private score
- The public score of each submission is posted in a public leaderboard in real time.
- Submission with the best private score wins the contest

How Kaggle contests work

Zillow Prize: Zillow's Home Value Prediction (Zestimate)

#	△	Team	Members	Score	Entries
1	▲ 9	Zensemble		0.07408	253
2	▲ 1	Juan Zhai 卷宅		0.07421	53
3	▲ 133	Silogram-2		0.07429	111
4	▲ 17	Alpha 60		0.07436	180
5	▲ 418	Jack (Japan)		0.07442	10
6	▲ 43	zhongtian		0.07451	63
7	▼ 6	dset / aichoo.ai		0.07456	449
8	▼ 2	R2		0.07457	352
9	▼ 1	Nima Shahbazi | mchahhou		0.07457	251
10	▼ 8	Zhishi Wang		0.07458	95
11	▲ 257	Victor S D		0.07459	61
12	▲ 204	alfie10		0.07472	250
13	—	To Train Them Is My Cause		0.07474	66
14	▲ 538	VVS0713		0.07477	69

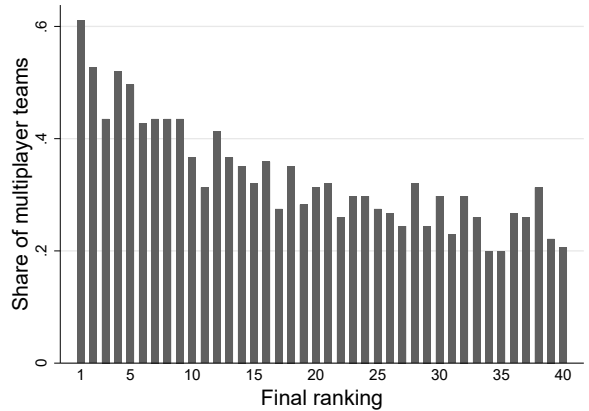
Data

For 131 featured Kaggle contests, we observe:

- Public and private scores for each submission
  - We standardize these to have mean 0 and std 1
  - Re-order to ensure higher scores are "better"
- Time and player/team identity of each submission
- Team formation (date and members)
- Players are free to form teams subject to some restrictions:
  1. Each member of a new team must have made at least one submission
  2. Team formation deadline
  3. Teams cannot disband

See summary statistics

Share of teamwork by final ranking



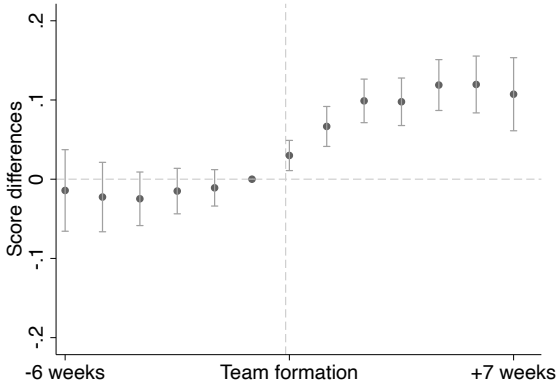
- On average, less than 10% of competitors in a contest form teams

Performance of self-organized teams

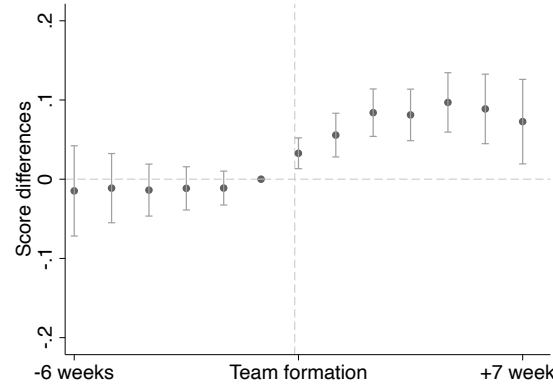
$$y_{i,j,c,t} = \beta \cdot 1\{\text{post team formation}\}_{i,j,c,t} + h(\mathbf{x}_{i,j,c,t}, \delta) + \mu_{j,c} + \lambda_{c,t} + \varepsilon_{i,j,c,t}$$

1. $y_{i,j,c,t}$ is an outcome variable i by "player" j (a team or a solo player) in competition c at time t
2. $1\{\text{post team formation}\}_{i,j,c,t}$
3. $\mathbf{x}_{i,j,c,t}$ is a vector of time-varying player-level state variables
4. $\mu_{j,c}$ player–competition fixed effects
5. $\lambda_{c,t}$ competition–time fixed effects
6. $\varepsilon_{i,j,c,t}$ is an error term clustered at the player level

Performance of self-organized teams

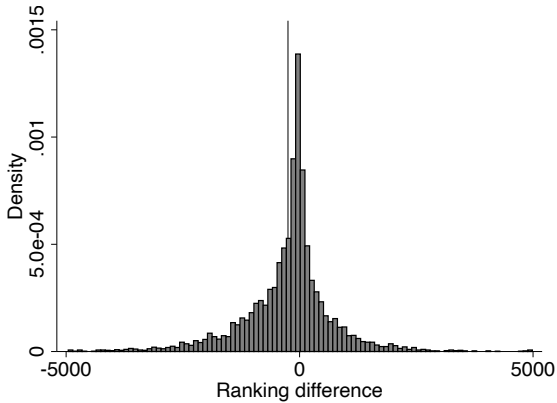


1) Full sample



2) Matched subsample

Impact on final outcomes



Rank difference relative to matched control team

Implications for contest design

- The competition sponsor's objective: finding the "best" solutions; diversity of solutions.
- Banning teamwork:
  $\rightarrow$ Less discouragement; give up on teamwork performance gains
- What are the outcomes without teamwork?
  In our data, we only observe contests that allow teamwork.
- We develop a structural model to measure the impact of banning teamwork and the cost of team formation.

Equilibrium effects of teamwork

N forward-looking players

State space:
Current maximum score, s.
Number of solo players, n^{SP}
Number of active teams, n^{teams}
Time, t

Constraint: $N = n^{SP} + 2n^{teams}$

Contest ends at time T.

Equilibrium effects of teamwork

At any time $t < T$:

With probability $\frac{\lambda_1}{N}$, a player can make a submission.
The player observes a submission cost $c \sim K^{sub}(\cdot)$.
The submission increases the max. score with probability $q^{SP}(s)$ *or* $q^{team}(s)$.
If the submission increases the max score, the player becomes leader.

- Asymmetry between followers and leader

Equilibrium effects of teamwork

At any time $t < T$:

Or with probability $\frac{\lambda_2}{N}$, a player can form a team.
The player observes a team-formation cost $c \sim K^{team}(\cdot)$.
The player is randomly matched with one of the followers.
The player chooses to form a team or continue solo.

- The player that proposes the team pays the team-formation cost

Equilibrium effects of teamwork

- At any period, there can be four types of players:
  1. a follower solo player
  2. a player that belongs to a follower team
  3. a player that belongs to the team leading the competition
  4. a solo player leading the competition

- The terminal values for each type of player are

$$F_{end}^{\text{sp}} = 0, \quad F_{end}^{\text{team}} = 0, \quad L_{end}^{\text{team}} = \frac{1}{2}, \quad L_{end}^{\text{sp}} = 1.$$

- Team members split the prize evenly in the event of winning the contest.

See value functions

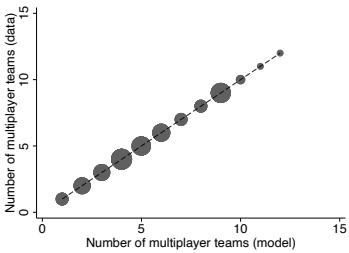
Estimation

- Search for parameters: model predictions $=$ data
  - Solve the model by backwards induction given a trial vector of parameters.

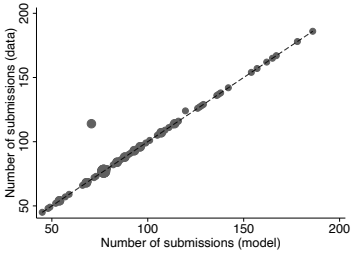
- Primitives:
  1. Probability that an active player can play, λ_1
  2. Probability that an active solo player can form a team, λ_2
  3. The functions $q^{\text{team}}(s)$ and $q^{\text{sp}}(s)$
  4. Distribution of submission and team-formation costs, $K^{sub}(c) = c^{\sigma_{sub}}$ and $K^{team}(c) = c^{\sigma_{team}}$, where $\sigma_j > 0$ and the support of the distribution is the interval $[0, 1]$

- We allow these primitives to vary by contest.

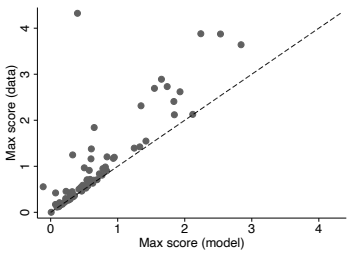
Model fit



A) Number of teams

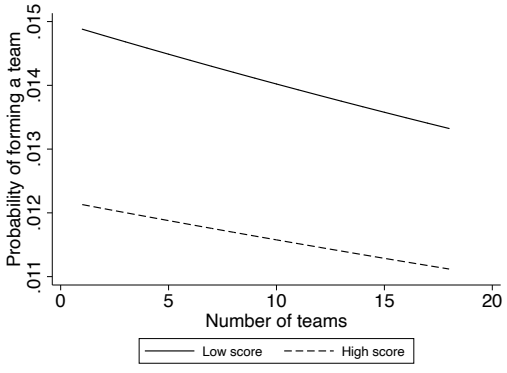


B) Number of submissions

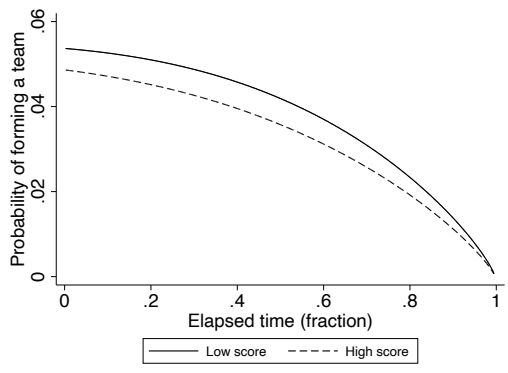


C) Maximum score

Properties of the equilibrium: probability of forming a team



A) Number of teams

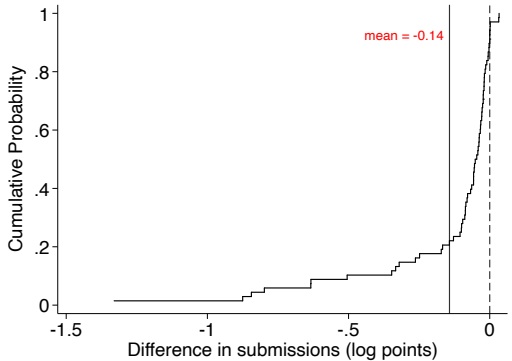


B) Time

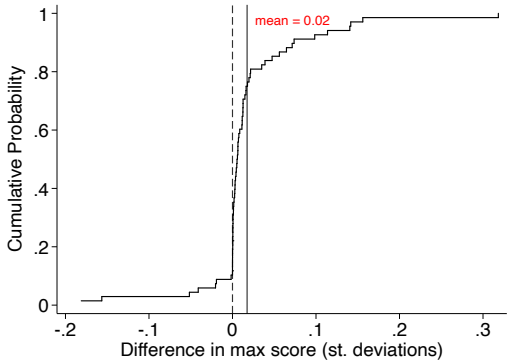
Counterfactual 1: Teamwork is allowed

	(1) Number of submissions (in logs)	(2) Maximum score
Teamwork allowed	-0.143***	0.018**
	(0.031)	(0.008)
Observations	136	136
R^2	0.898	0.998

Counterfactual 1: Teamwork is allowed



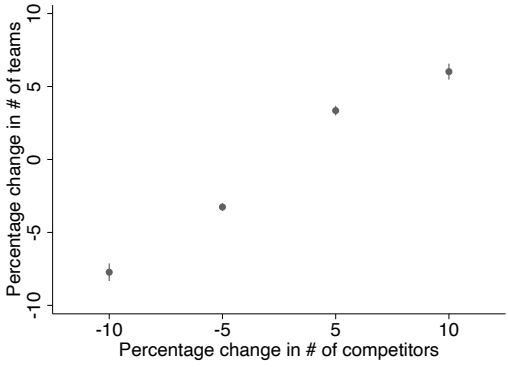
A) Number of submissions



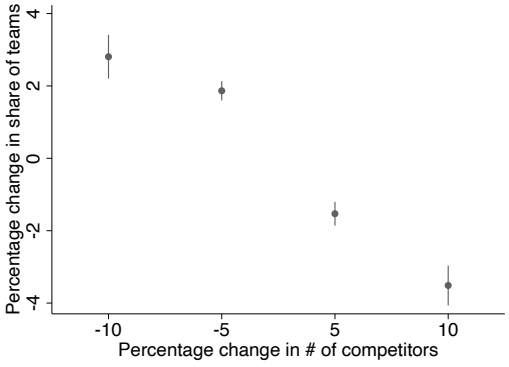
B) Maximum score

Notes: The figures plot a comparison of equilibrium outcomes when allowing teamwork versus when teamwork is banned. An observation is a contest.

Counterfactual 2: Increasing competition

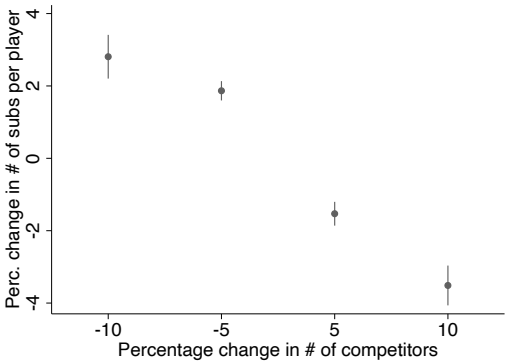


A) Number of teams

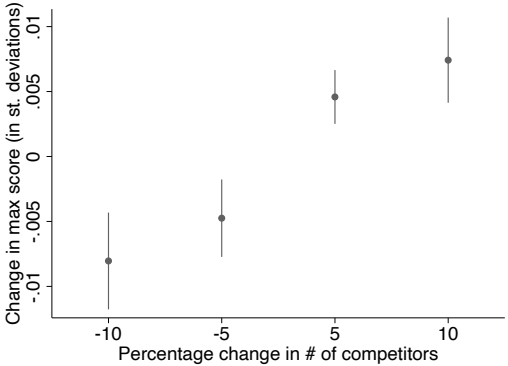


B) Fraction of team members

Counterfactual 2: Increasing competition



C) Number of submissions per player



D) Maximum score

Summary

- Evidence that self-organized teams improve performance
- These performance gains discourage rivals, creating a tradeoff for the contest designer
- Propose a model that allows for endogenous team formation
- On average, the equilibrium maximum score increases when allowing teamwork
  - Heterogeneity across contests
- Competition intensity increases the number of teams and the equilibrium max score
  - Forming a team is a way to escape competition

Thank you!

Data

131 featured Kaggle contests:

	Mean	St. Dev.	Min	Max
	(1)	(2)	(3)	(4)
Number of submissions	27,922	33,376	627	159,810
Number of players	1,781	1,928	57	11,111
Number of competitors	1,676	1,818	55	10,450
Percentage of solo players	90.18	5.15	71.60	98.42
Reward quantity (USD)	54,699	136,093	5,000	1,200,000

Go back

The model (in equations)

A solo-player follower's value at state $(s, \ell, n = (n^{\text{sp}}, n^{team}), t)$ is

$$
\begin{aligned}
F^{\text{sp}}_{s,\ell,n,t} \quad = \quad & \frac{\lambda_1}{N} E_{c^{\text{sub}}} \left[\max\{q^{\text{sp}}(s) L^{\text{sp}}_{s',0,n,t'} + (1 - q^{\text{sp}}(s)) F^{\text{sp}}_{s,\ell,n,t'} - c^{\text{sub}}, F^{\text{sp}}_{s,\ell,n,t'}\} \right] + \\
& \frac{\lambda_2}{N} E_{c^{\text{team}}} \left[\max\{F^{\text{team}}_{s,\ell,(n^{\text{sp}}-2,n^{\text{a}}+1),t'} - c^{\text{team}}, F^{\text{sp}}_{s,\ell,n,t'}\} \right] + E[V^{\text{sp, F}}_{s',\ell',n',t'} | (s, \ell, n, t)].
\end{aligned}
$$

The conditional choice probabilities are given by

$$
\begin{aligned}
p^{sub,sp,F}_{s,\ell,n,t} \quad &= \quad \Pr(c^{sub} < q^{\text{sp}}(s)(L^{\text{sp}}_{s',0,n,t'} - F^{\text{sp}}_{s,\ell,n,t'})) \\
p^{\text{team forms}}_{s,\ell,n,t} \quad &= \quad \Pr(c^{team} < F^{\text{team}}_{s,\ell,(n^{\text{sp}}-2,n^{\text{a}}+1),t'} - F^{\text{sp}}_{s,\ell,n,t'})
\end{aligned}
$$

Go back