Market-Bound Research Contests

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  - → Making cars more fuel-efficient;
  - → Making household appliances more energy-efficient;
  - → Stopping antibiotic-resistant bacteria through less antibiotic overuse.

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  - → 2007 Automotive X Prize;
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  - → 2015 Better Use of Antibiotics prize.
- A problem: contestants will tailor the innovation to meet the specific rules of the contest.

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There are lots of competitions to make hyper-efficient cars – but often they look like rolling coffins. [...] We wanted a focus on consumer desirability.

A problem: rolling coffins.

An old problem, too.

- In 1714, the British government offered a prize of £20,000 for a method of determining longitude at sea, accurate to within one-half of a degree.
- John Harrison solved the challenge by building a very precise watch.
- Board of Longitude refused to give him the prize.
- Why? One popular explanation was the Board was biased (Sobel, 1995).
- Another is that the Board refused because Harrison's solution was not practical – building a copy of his watch took two years (Siegel, 2009).

Different approach: 1992 Super-Efficient Refrigerator Prize.

Los Angeles Times

A Cool $30 Million : 14 Entries Vie for Prize in Super-Refrigerator Contest

By MICHAEL PARRISH

Oct. 21, 1992 12 AM PT

Market-bound contests

- The size of the prize can depend on the market performance of the winner.
- In the 1992 Super-Efficient Refrigerator Prize, per unit subsidy.
- But that is just one way of binding the prize to the market outcomes!
- The goal of this paper:
  - $\rightarrow$ Is it optimal (and if so when) to condition prizes on market performance?
  - $\rightarrow$ What is the optimal way to condition prizes on market performance?

Main results

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   - → Among all ways to condition on market performance, the best (weakly) is to set quantity targets and rewards when those targets are met. This is true both for incentives that address research direction and for diffusion of innovation.

Main results

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   → With increasing returns to scale in innovation technology the only way to promote the development of products that both resolve the externality and have broad appeal.
2. Quantity cutoff designs provide the best incentives.
   → Among all ways to condition on market performance, the best (weakly) is to set quantity targets and rewards when those targets are met. This is true both for incentives that address research direction and for diffusion of innovation.
3. When the budget is limited the “rolling coffin” innovations should not be ignored.
   → Trade-off between incentivizing diffusion between “rolling coffin” innovations and innovations with broad appeal.

Related literature

1. Design of general contests.
2. Dynamic research contests:
   → Taylor (1995, AER), Benkert and Letina (2020, AEJ:Micro), Chen, Chen and Knyazev (2022, RAND).
3. Static research contests:
   → Che and Gale (2003, AER), Letina and Schmutzler (2020, IER), Rietzke and Protopappas (2023, WP).
4. Advanced Market Commitments:
   → Kremer (2000a, b, IPE), Kremer, Levin, and Snyder (2020, AEA P&P), Kremer, Levin, and Snyder (2022, ManSci).

Model

Model

- Two ex-ante symmetric firms that can innovate.
- Two types of innovations: desirability (d) and externality (e).
- Each firm has two labs, and the action of the firm a_i is to direct the labs to either pursue desirability or externality innovation:

  $\rightarrow$ $a_i \in \{DD, EE, DE\}$.
- Innovation is stochastic.

Innovation Technology

- If $a_i = DD$, the innovation outcome is

$$(d_i, e_i) = \begin{cases} (1,0), & \text{with probability } p, \\ (0,0), & \text{with probability } 1-p. \end{cases}$$

- If $a_i = EE$,

$$(d_i, e_i) = \begin{cases} (0,1), & \text{with probability } p, \\ (0,0), & \text{with probability } 1-p. \end{cases}$$

Innovation Technology

- If $a_i = DE$,

$$(d_i, e_i) = \begin{cases} (1,0), & \text{with probability } q(1-q), \\ (0,1), & \text{with probability } q(1-q), \\ (1,1), & \text{with probability } q^2, \\ (0,0), & \text{with probability } 1-2q+q^2. \end{cases}$$

- $q < p$
- Whether $q < p \leq 2q$ (decreasing returns to scale in innovation) or $2q < p$ (increasing returns to scale in innovation) will be crucial.
- Assume that successful innovations are patentable.
- Firm will have patents $t \in T = \{d, e, de, \emptyset\}$.

Consumers

- There is a total mass 1 of consumers.
- Heterogeneous in two dimensions.
- Vertical: $\theta \sim \mathcal{U}_{[0,1]}$ – willingness to pay.
- Horizontal: $\eta = \begin{cases} \delta, & \text{w.p. } m_d \\ \varepsilon, & \text{w.p. } 1 - m_d \end{cases}$
- δ-consumers only care about the desirability feature of the product;
- ε-consumers – only about the externality.
- $\eta \perp\!\!\!\perp \theta$

Consumers

- The utility of a consumer with the type (θ, δ) from buying the product from this firm i is

$$U(i|\theta, \delta) = \theta \times \mathbb{I}_{\{t_i = d \text{ or } t_i = de\}} - p_i.$$

- Similarly, for consumer with the type (θ, ε)

$$U(i|\theta, \varepsilon) = \theta \times \mathbb{I}_{\{t_i = e \text{ or } t_i = de\}} - p_i.$$

- Market demand for desirability products: $m_d(1 - p)$.
- Market demand for externality products: $(1 - m_d)(1 - p)$.
- Assume $m_d > 1/2$ ($\iff m_d > 1 - m_d$).

Contest Design

- Maximal budget B, the principal does not value leftover money.
- A market-bound contest: reward function $b : [0,1] \to [0,B]$ for a firm with an externality patent.
- If a firm i has an externality patent and sells Q_i, the principal commits to paying $b(Q_i)$ to i.
- We assume b is non-decreasing.

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- Examples:
  - $\to$ If $b(Q_i) = P$ for all $Q_i \to$ fixed-prize tournament.
  - $\to$ If $b(Q_i) = sQ_i \to$ per-unit subsidy.
  - $\to$ If $b(Q_i) = P$ if $Q_i \geq Z^I$ and zero otherwise $\to$ single-cutoff contest.

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  - $\to$ If $b(Q_i) = P$ if $Q_i \geq Z^I$ and zero otherwise $\to$ single-cutoff contest.
- What is the optimal choice for b?

Principal's objective

- Objective 1 (research direction): Implementing (DE, DE).
  - $\rightarrow$ What is the contest (i.e., the function b) that implements (DE, DE) at the minimal cost?
  - $\rightarrow$ What is the minimal budget needed?
  - $\rightarrow$ How do alternative contests perform?

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  - $\rightarrow$ How do alternative contests perform?
- Objective 2 (diffusion): Conditional on implementing (DE, DE), maximizing diffusion of the product with e-innovation.
  - $\rightarrow$ What is the optimal contest?
  - $\rightarrow$ Should "rolling coffin" innovations be subsidized?

Timeline

Period 0:

- Nature randomly and privately determines the success of research activities and the allocation of patents.

Period 1:

- The principal commits to a contest reward function b.

Period 2:

- Firms simultaneously choose the innovation activity a_i and a_j.
- The actions taken by Nature and both firms become public knowledge.
- Patents are allocated and firm types t_i and t_j are realized.

Period 3:

- Firms simultaneously choose prices ρ_i and ρ_j.
- Payoffs are realized.

Analysis

Contest design

- Complex problem.
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Contest design

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- We simplify by focusing – without loss – on a particular class of contests.
- A two-cutoff contest:

$$b^{t.c.} = \begin{cases} 0, & \text{if } Q \in [0, Q^I), \\ Z^I, & \text{if } Q \in [Q^I, Q^{II}), \\ Z^{II}, & \text{if } Q \geqslant Q^{II}. \end{cases}$$

Optimality of two-cutoff contests

Proposition 1

Fix any contest, any SPNE of that contest $(a_1^*, \rho_1^*(), a_2^*, \rho_2^*())$, and any pricing function $\hat{\rho}(t)$ such that $\hat{\rho}(t) \in \{\rho_1^*(t), \rho_2^*(t)\}$ for all $t \in T$. Then, there exists a two-cutoff contest with an SPNE $(a_1^{tc}, \rho_1^{tc}(), a_2^{tc}, \rho_2^{tc}())$ such that:

1. $a_1^{tc} = a_1^*$ *and* $a_2^{tc} = a_2^*$;
2. $\rho_1^{tc}(t) = \rho_2^{tc}(t) = \hat{\rho}(t)$ *for all* $t \in T$.

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2. $\rho_1^{tc}(t) = \rho_2^{tc}(t) = \hat{\rho}(t)$ *for all* $t \in T$.

- Result would hold if there were more than two firms, more than two labs, more than two groups of consumers.
- What is crucial for the result: two types of winners: $t = e$ and $t = de$.

Budget needed to implement (DE, DE)

Proposition 2

1. *If $p > 2q$, (DE, DE) is implementable iff $B \geq \frac{m_d(p-q(2-2q+q^2))}{2(2-q)q^2} - \frac{1}{4}$. A contest implementing it is $Q^I = \frac{1-m_d}{2}$, $Q^{II} = \frac{1}{2}$, $Z^I = \frac{2m_d-1}{4}$ and $Z^{II} = \frac{m_d(p-q(2-2q+q^2))}{2(2-q)q^2} - \frac{1}{4}$.*

- $p > 2q$ (increasing returns to scale in innovation)
  - $\rightarrow$ Q^{II} only achievable for $t_i = de$.
  - $\rightarrow$ $Z^I < Z^{II}$.
  - $\rightarrow$ $0 < Z^I$.

Budget needed to implement (DE, DE)

Proposition 2

2. *If $p \leq 2q$, (DE, DE) is implementable iff $B \geq \frac{m_d p - q}{4q}$. A contest implementing it is $Q^I \leq Q^{II} \leq \frac{1-m_d}{2}$ and $Z^I \leq Z^{II} = \max\left\{\frac{m_d p - q}{4q}, 0\right\}$.*

- $p \leq 2q$ (decreasing returns to scale in innovation):
  - → Q^I and Q^{II} achievable for any winning type.
  - → Any winner gets Z^{II}.

Implementability of (DE, DE) with a FPT

Proposition 3

Suppose that $p > 2q$. Then, given any fixed-prize contest, (DE, DE) is not an equilibrium.

Research direction

- When $p > 2q$ (increasing returns to scale in innovation), the research direction problem is more challenging and (DE, DE):
  - $\rightarrow$ can never be implemented with a fixed-prize tournament;
  - $\rightarrow$ can be implemented with a single-cutoff contest and per-unit subsidy, but at a higher cost;

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- When $p > 2q$ (increasing returns to scale in innovation), the research direction problem is more challenging and (DE, DE):
  - $\rightarrow$ can never be implemented with a fixed-prize tournament;
  - $\rightarrow$ can be implemented with a single-cutoff contest and per-unit subsidy, but at a higher cost;
- When $p \leq 2q$ (decreasing returns to scale in innovation), the research direction problem is easy.
  - $\rightarrow$ (DE, DE) can be implemented also with a fixed-prize tournament, a single-cutoff contest or a per-unit subsidy.
  - $\rightarrow$ "Rolling coffins" not a problem.

Moving on: The diffusion problem

- Principal would like to maximize the expected quantity of the good with the e-innovation, given that firms play (DE, DE).
- Choose Q^I, Q^{II}, Z^I and Z^{II} that minimizes prices set by firms with e and de patents.
- Call $\underline{Z}^{II}$ the minimal budget needed to implement (DE, DE).

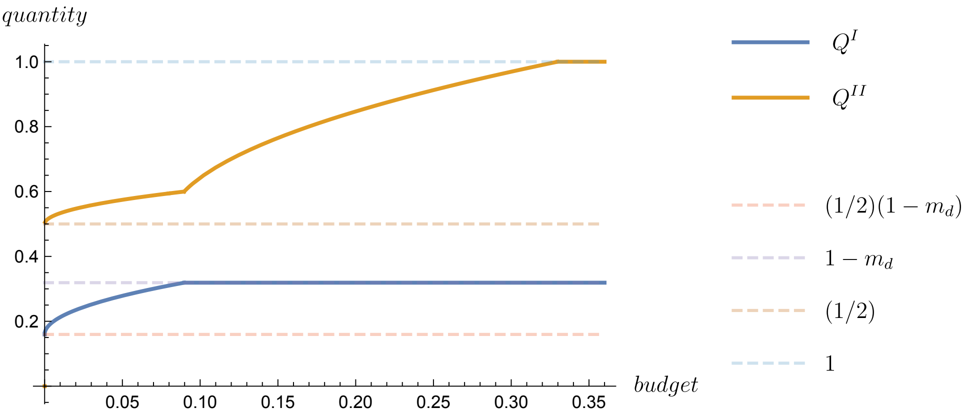
Optimal diffusion

Proposition 4

There exist budget thresholds $\underline{Z}^{II} \leq Z^{II,E} \leq \overline{Z}^{II}$.

1. *If* $B \in [\underline{Z}^{II}, Z^{II,E})$*, the optimal diffusion is between monopoly level and the first-best both when the winner has only* e*-innovation as well as* de*-innovation (*$Q^I < 1 - m_d$*,* $Q^{II} < 1$*).*
2. *If* $B \in [Z^{II,E}, \overline{Z}^{II})$*, the optimal diffusion is between monopoly level and the first-best for a firm with a* de*-innovation (*$Q^{II} < 1$*), but equals first-best for the firm with an* e*-innovation is (*$Q^I = 1 - m_d$*).*
3. *If* $B \geq \overline{Z}^{II}$*, first-best is achievable (*$Q^I = 1 - m_d$*,* $Q^{II} = 1$*).*

Optimal diffusion



Wrapping up

Conclusion

- We look at how research contests can be used to induce innovation that both resolves an externality and generates desirable products.
- Three lessons:
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- Three lessons:
  1. research contests which condit on market performance are useful;
  2. quantity cutoff designs provide best incentives;
  3. to maximize diffusion, focus on groups that intrinsically care about the externality.

Thank you!

Appendix

Payoffs

- Given a fixed patent allocation (t_i, t_j) and a price $\rho_i \in [0,1]$, firm i's payoffs are

$$
\begin{aligned}
\pi_i(\rho_i; t_i) = & m_d(1-\rho_i)\rho_i \mathbb{I}_{\{t_i=d\}} + \\
& \left[(1-m_d)(1-\rho_i)\rho_i + b((1-m_d)(1-\rho_i))\right] \mathbb{I}_{\{t_i=e\}} + \\
& \left[(1-\rho_i)\rho_i + b(1-\rho_i)\right] \mathbb{I}_{\{t_i=de\}}.
\end{aligned}
$$

- Let $\rho_i^*(t_i)$ be the profit maximizing price given patents t_i.

Payoffs

- Let $\mathbb{P}\{t_i, t_j | a_i, a_j\}$ be the probability that the subgame (t_i, t_j) is reached and let

$$\mathbb{P}\{t_i | a_i, a_j\} = \sum_{t_j \in T} \mathbb{P}\{t_i, t_j | a_i, a_j\}.$$

- i's payoff, when it chooses research strategy a_i and the opponent chooses a_j is

$$\Pi_i(a_i, a_j) = \sum_{t_i \in T} \mathbb{P}\{t_i | a_i, a_j\} \pi_i(\rho_i^*(t_i); t_i).$$