Resource Allocation across Fields: Proportionality, Demand Relativity, and Benchmarking

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Thorniest question in research funding

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Impact of proportional allocation on application incentives?

Paul Romer's *meta-idea*, supporting production and diffusion of other ideas

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- Total budget T assigned to panels $i = 1, 2, ..., N$ representing fields
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  - budget allocated to field i follows proportional formula

$$\frac{A_i}{\sum_{j=1}^{N} A_j} T$$

". . . budget is calculated as the **cumulative grant request of all proposals to the panel** **<u>divided</u>** *by the* **cumulative grant request of all proposals** *to the domain of the call,* **<u>multiplied</u>** *by the* **total indicative budget** *of the domain."*

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Concern that proportional allocation dis/favors certain fields...

Proportional Allocation Equalizes Success Rates

- Under proportional allocation, the *success rate* in field i is

$$\frac{\overbrace{\frac{A_i}{\sum_{j=1}^{N} A_j} T}^{\text{budget available for funding projects in field } i}}{\underbrace{A_i}_{\text{budget demanded by applications in field } i}} = \frac{T}{\sum_{j=1}^{N} A_j} =: p,$$

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- NIH payline system with percentiled scores is proportional in disguise
  - Congress assigns separate budgets to each of 27 IC
  - Each IC awards grants to applications to different study sections (≈180) in top $100 \times p_{IC}\%$ of percentiled scores
    - payline p_{IC} set to exhaust IC's budget

Model

- Field i with continuum of risk-neutral potential applicants [=agents]
- Atomistic agents disregard their negligible impact on success rate p
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- For every applicant, evaluator observes **signal** $x \sim F_i^{\theta,\sigma_i}$

$$F_i^{\theta,\sigma_i}(x) = F_i\left(\frac{x-\theta}{\sigma_i}\right) \tag{1}$$

with location θ (agent type) & scale σ_i (signal noise/dispersion)

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- Assume: G_i and F_i with continuous densities + f_i **logcav** [⇔MLRP]

What's Next?

Proportional Allocation Method

Analyze model with costly applications in terms of **demand & supply**:

1. Characterize *partial equilibrium* in **SMALL panel**, GIVEN payline p
   - Panel experts [evaluator] select best $100 \times p\%$ submissions

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1. Characterize *partial equilibrium* in **SMALL panel**, GIVEN payline p
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2. Determine **full equilibrium** with endogenous success rate

$$p = \frac{T}{\sum_{j=1}^{N} A_j},$$

   - success rate responds to applications in own field &
   - applications in other fields respond to success rate

Partial Equilibrium in Small Field i, for Given p

Timing:

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- Demand: higher θ agents are accepted w/ higher prob, thus apply for

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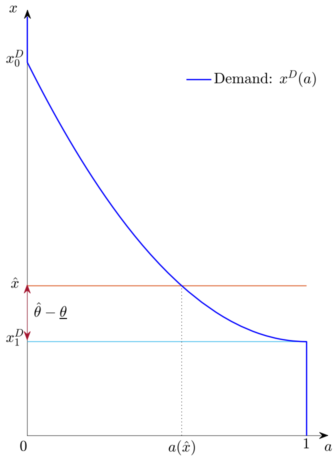
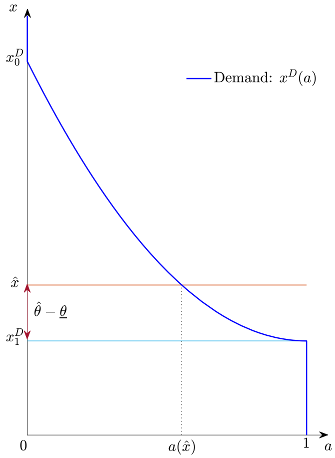
Demand

Acceptance **standard** $\hat{x}$ [like price] against **demand** $a^D(\hat{x})$



Demand

- When standard $\hat{x} \uparrow$, win prob is lower for all applicants:
  - fewer agents apply, $a \downarrow$; marginal applicant $\hat{\theta} \uparrow$



Proportional Supply for Fixed Payline

When top a agents apply, pa applications are accepted, so $\hat{x}^S(a)$ solves

$$\int_{G^{-1}(1-a)}^{\bar{\theta}} \left[1 - F\left(\frac{\hat{x}-\theta}{\sigma}\right)\right] g(\theta) d\theta = pa$$

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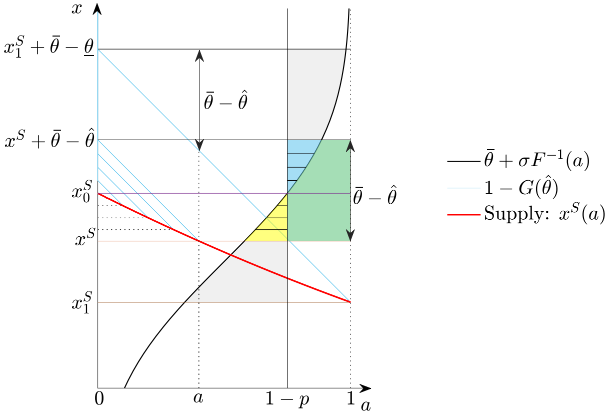

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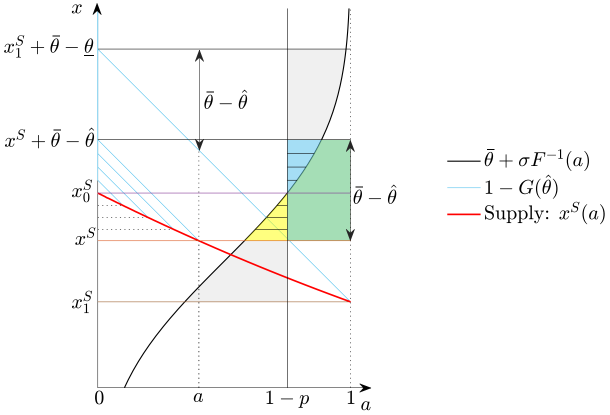

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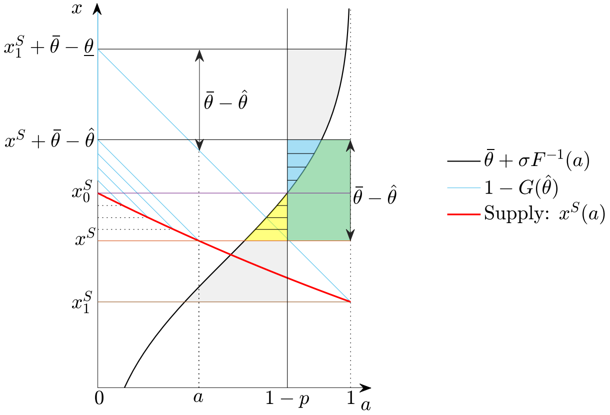
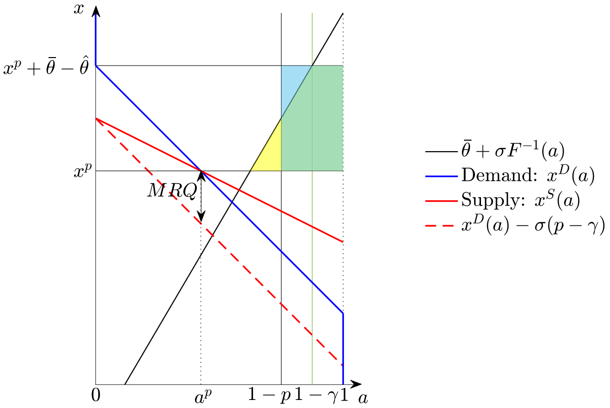
Proportional Supply for Fixed Payline

Proportional **supply** [in RED] curve **slopes down!**

- as $a \uparrow$, average applicant quality$\downarrow$, so $\hat{x} \downarrow$ to award constant fraction p



Partial Equilibrium for Fixed Payline



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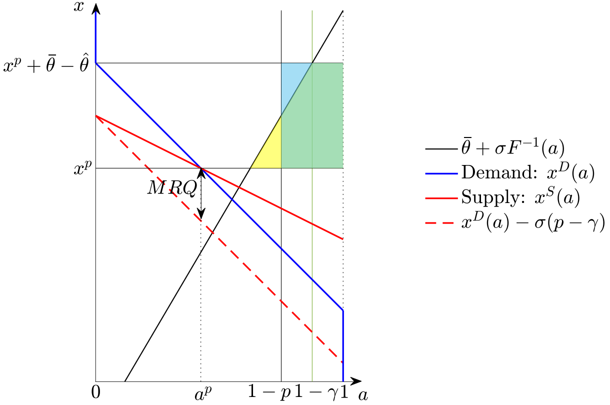

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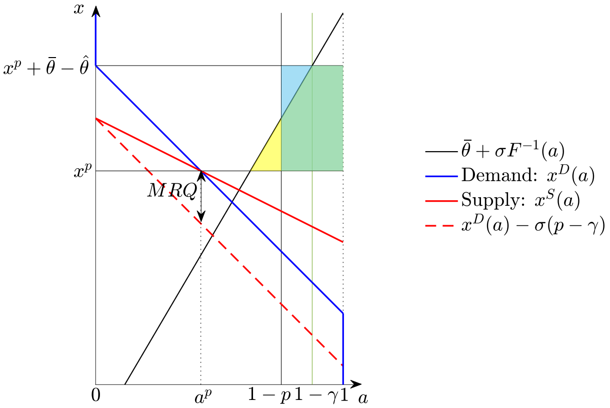

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When does this hold? What happens more generally?

Preview of Insights

Proportional Allocation Method

We head to show that:

1. "realistic" conditions $\Rightarrow$ **MULTIPLE equilibria**

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5. perverse incentives are enhanced by **STRATEGIC** *behavior by fields*

When is Equilibrium Unique?

Proposition

(a) If in every field i the type distribution has Increasing Hazard Rate (HR)

$$\frac{d}{d\theta}\frac{g_i(\theta)}{1-G_i(\theta)} \geq 0,$$

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- *provided they are not much worse*
- thus justifying initial expectation

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When success is difficult to predict, strong incentives to apply!

Unique Equilibrium Path as Noise Increases

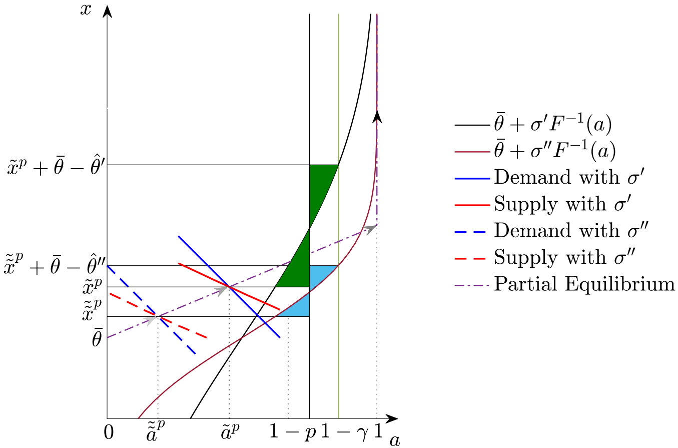

Figure: Partial equilibrium path as signal dispersion σ increases in example with G uniform and F normal.

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- $\sigma \to 0$, signal becomes **perfectly informative**
  - applicants know $x = \theta$, so spend c if they are SURE to win
  - but only a FRACTION $p < 1$ of these applicants must win...
  - so, unique equilibrium ALWAYS **unravels**, with nobody applying!
- **Type distr. w/ thick tail:** $HR(\underline{\theta}) \Rightarrow$ **unraveling for** $\sigma < \bar{\sigma}$ **for** $\bar{\sigma} > 0$

Type Distribution with Thick Tail: Multiplicity

Example: 1 panel with G Pareto-Lomax & 1 panel with G uniform

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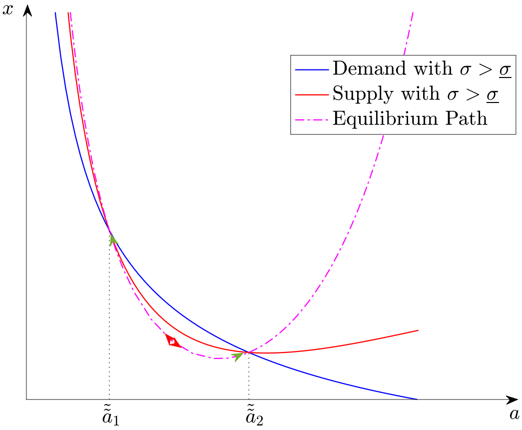

$\sigma_a > \underline{\sigma}_a$: 1 stable unraveling eq + 2 interior eq: unstable & stable

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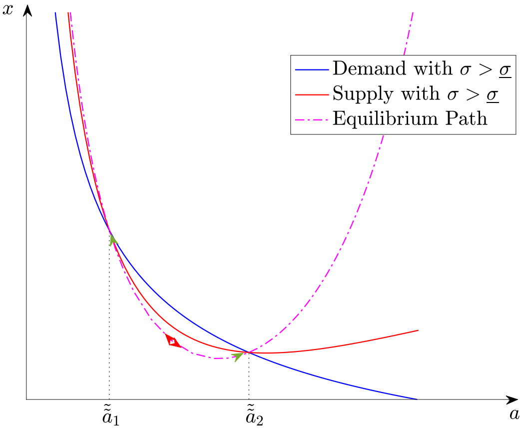

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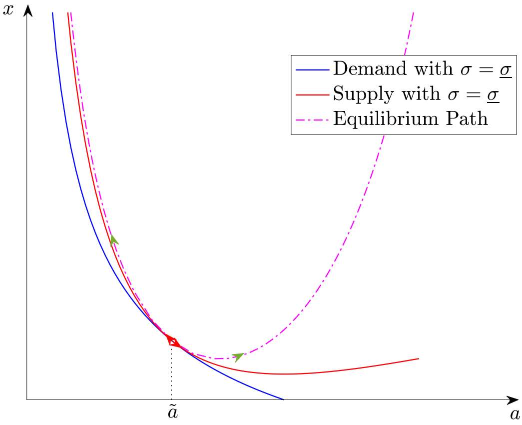
Full equilibrium path as σ increases

Type Distribution with Thick Tail: Tipping and Unraveling



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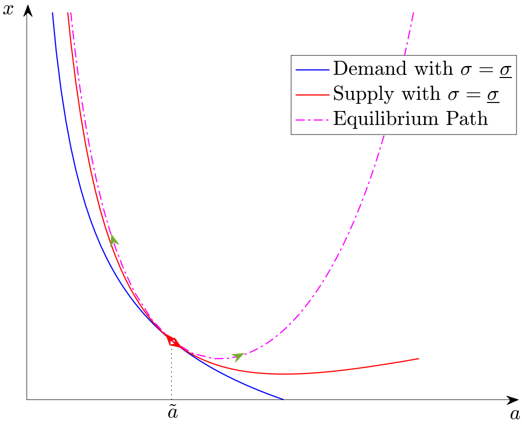

For $\sigma_a < \underline{\sigma}_a$, with $\underline{\sigma}_a > 0$: ONE stable equilibria w/ unraveling!

Comparison of ERC Grants: 2008-14 v. 2014-20

Google scholar citations for Advanced Grant PIs (principal investigators)

ERC Panel code (0)	Average citations 2008-14 (1)	**Variability in citations 2008-14 (2)**	Average citations 2015-20 (3)	Variability in citations 2015-20 (4)	**´% budget fraction (5)**
LS1	389.82	**1.65**	467.58	2.21	**–21.52%**
...	...	**...**	...	...	**...**
PE1	192.08	**1.55**	208.66	1.51	**–27.27%**
...	...	**...**	...	...	**...**
PE10	274.99	**1.03**	345.64	1.37	**11.1%**
SH1	418.12	**1.73**	654.4	1.29	**–0.31%**
SH2	260.58	**1.54**	413.79	1.88	**–1.59%**
SH3	220.79	**1.34**	290.04	1.43	**46.22%**
SH4	323.44	**1.19**	441.44	0.94	**0.15%**
SH5	35.8	**2.27**	109.66	2.89	**91.45%**
SH6	101.95	**1.9**	270.96	2.84	**15.74%**

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Panels with **higher variability** in PI citations in **first period**:

- in second period obtain **more funding**
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- Correlation 0.27 between:
  - coefficient of variation of citations in the first period (column 2)
  - growth in funding from first to second period (column 5)

- Correlation -0.16 between:
  - coefficient of variation of citations in the first period (column 2)
  - average citations in the second period (column 3)

ERC v. NSF

NSF's success rates vary across fields:

- **pure science higher success rates** than applied science

ERC v. NSF

NSF's success rates vary across fields:

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Fields with **higher success rate** at NSF

- have been attracting **declining** proportion of budget at ERC

(In)efficiency

Consider:

- $N = 2$ fields otherwise identical fields with $\sigma_1 = 0$ & $\sigma_2 = \infty$

(In)efficiency

Consider:

- $N = 2$ fields otherwise identical fields with $\sigma_1 = 0$ & $\sigma_2 = \infty$
- Proportional allocation assigns all funds in field 2, randomly
  - in this admittedly extreme, **worst possible** system!

Optimizing Allocation Formula

Social welfare

$$W = \sum_{i=1}^{N} \int_{\hat{\theta}_i}^{\overline{\theta}} \{ \int_{\hat{x}_i}^{\overline{x}} [\underbrace{E\left(\theta | x; \theta \geq \hat{\theta}_i\right) - f_i}_{\substack{\text{evaluator} \\ \text{expected net merit}}} + \underbrace{v_i}_{\substack{\text{agent} \\ \text{benefit}}}] f\left(x|\theta\right) dx - \underbrace{c_i}_{\substack{\text{agent} \\ \text{cost}}} \} g\left(\theta\right) d\theta$$

where

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Some proportionality is desirable if $\frac{c_i}{v_i} \neq \frac{c_j}{v_j}$ [NIH]

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$$W = \sum_{i=1}^{N} \int_{\hat{\theta}_i}^{\overline{\theta}} \{ \int_{\hat{x}_i}^{\overline{x}} [\underbrace{E\left(\theta | x; \theta \geq \hat{\theta}_i\right) - f_i}_{\substack{\text{evaluator} \\ \text{expected net merit}}} + \underbrace{v_i}_{\substack{\text{agent} \\ \text{benefit}}}] f(x|\theta)\, dx - \underbrace{c_i}_{\substack{\text{agent} \\ \text{cost}}} \} g(\theta)\, d\theta$$

where

- $E\left(\theta | x; \theta \geq \hat{\theta}_i\right)$ incorporates self-selection into applying
- f_i is evaluator opportunity cost of funds for field i

Some proportionality is desirable if $\frac{c_i}{v_i} \neq \frac{c_j}{v_j}$ [NIH]
less so with highly heteregeneous dispersion $\sigma_i \neq \sigma_j$ [ERC]

Adjusting Proportionality ρ

Sub/super-proportional $\rho \lesseqgtr 1$ allocation formula:

$$p(A_i, A_j) := \frac{\overbrace{\frac{\alpha_i A_i^{\rho}}{\sum_{j=1}^{N} \alpha_j A_j^{\rho}} T}^{\text{budget available for funding projects in field } i}}{\underbrace{A_i}_{\text{budget demanded by applications in field } i}} = \frac{T \alpha_i A_i^{\rho-1}}{\sum_{j=1}^{N} \alpha_j A_j^{\rho}}$$

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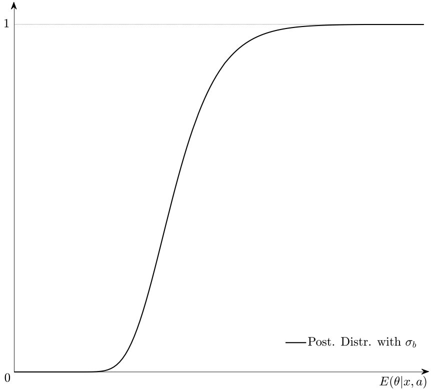
- Increase in proportionality, responsiveness of applications $\uparrow$

$$\frac{\partial}{\partial \rho}\left(\frac{\partial a_i}{\partial \sigma_i}\right) > 0$$

NIH Benchmarking Against Scores in Previous Cycle

Clever Design Tweak: Improves Accuracy Incentives!

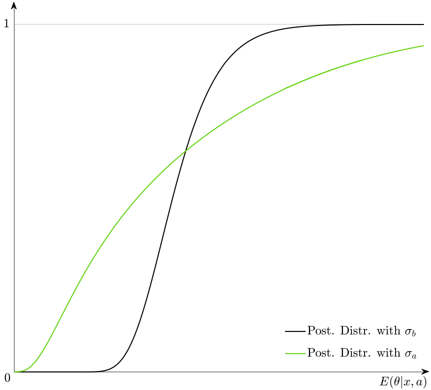
Distribution of **previous** scores $E[\theta|b,x]$, from normal signal with σ_b



NIH Benchmarking Against Scores in Previous Cycle

Clever Design Tweak: Improves Accuracy Incentives!

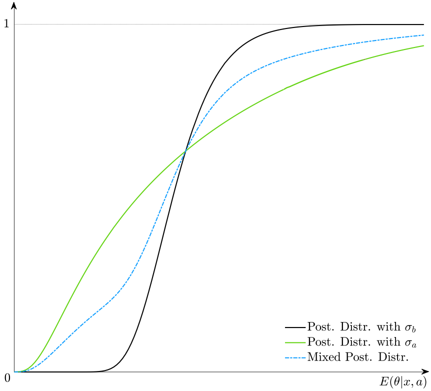
With $\sigma_a < \sigma_b$, **current** scores $E[\theta|a,x]$ are *MORE* dispersed



NIH Benchmarking Against Scores in Previous Cycle

Clever Design Tweak: Improves Accuracy Incentives!

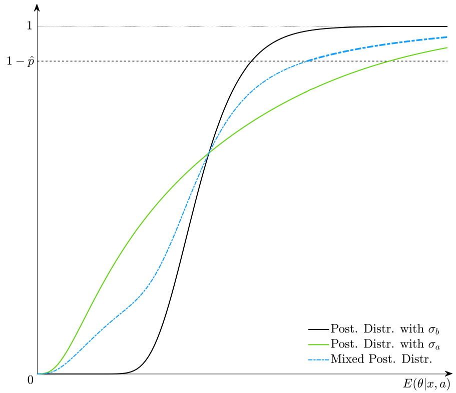
Mixture distribution of **current** & **previous** scores



NIH Benchmarking Against Scores in Previous Cycle

Clever Design Tweak: Improves Accuracy Incentives!

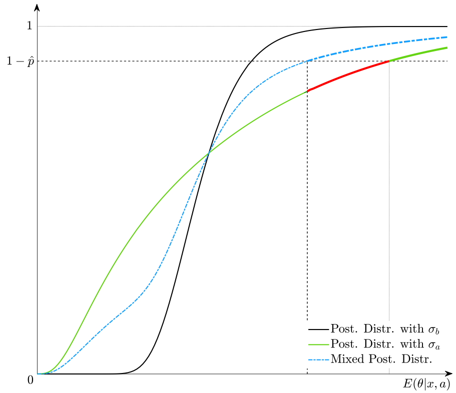
Projects above payline $\hat{p}$



NIH Benchmarking Against Scores in Previous Cycle

Clever Design Tweak: Improves Accuracy Incentives!

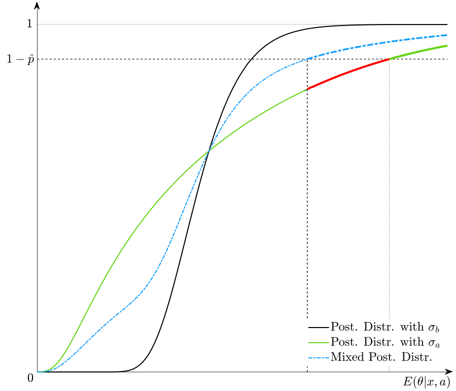
With improved accuracy, more applications win—extra RED



Interpretation: Panel with Subfields

Implications for Panel Design

Same logic for panels made up of multiple subfields: clinical v. basic



Field Game

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  - advertising availability of grants & supporting applications through
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$$\max_{a_i} \underbrace{v_i p\left(a_i, a_{-i}\right)}_{\text{inverse demand } P_i(a_i, a_{-i}) = \frac{T}{a_i + a_{-i}}} a_i - \underbrace{c_i}_{\text{marginal cost}} a_i$$

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Proposition

In unique interior equilibrium of the field game, applications in field i are $a_i^{(N)} = (N-1)\, T \frac{\sum_{j=1}^N \gamma_j - (N-1)\gamma_i}{\left(\sum_{j=1}^N \gamma_j\right)^2}$ *with payline* $p = \frac{\sum_{j=1}^N \gamma_j}{N-1}$. *If fields have identical* $\gamma_i = \gamma$, *equilibrium surplus in each field is* vT/N^2 *& total surplus is* vT/N. *In limit as* $N \to \infty$, *the success rate* $p \to \gamma^+$ *and surplus of each field as well as the total surplus of all fields converges to zero.*

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  - hands off: robust to lobbying/meddling by politicians/administrators

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- Academic **journals** subject to a similar, but informal, pressure to:
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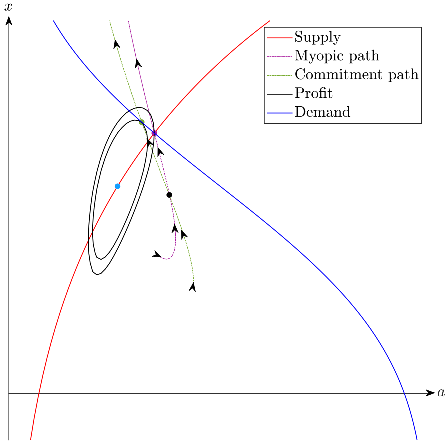
- Similarly, **university admission** boards are tempted to:
    - admit students to different programs in proportion to applications, or
    - increase slots available in areas that attract more applications...

Senior Applicants

Know Well Their Quality

Evaluator optimally commits to raise standard: $\hat{x}^E > \hat{x}^N$

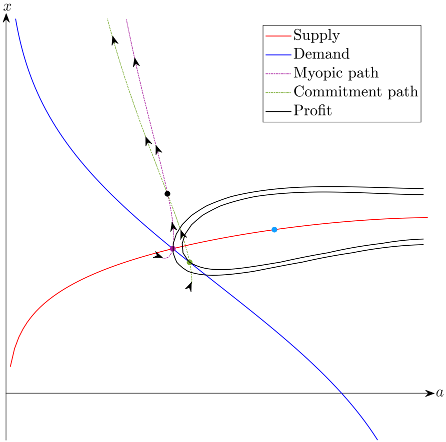


Evaluator bliss point $(a_E^*, \hat{x}_E^*)$ to South West of (a^N, x^N)

Junior Applicants

Know Poorly Their Quality

Evaluator optimally commits to reduce standard: $\hat{x}^E > \hat{x}^N$



Evaluator bliss point $(a_E^*, \hat{x}_E^*)$ to North East of (a^N, x^N)