Experimental Design as Market Design

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Golden Age of Randomized Experiments

Randomized Controlled Trials (RCT) or A/B tests
=Gold standard of evidence-based decision-making in

1. Medicine
2. Social Policy
3. Web

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Poverty Action Lab

ipa
INNOVATIONS FOR
POVERTY ACTION

- Stake is often high & sometimes life-or-death
  (especially in 1 & 2; e.g. cancer & malaria treatment, basic income)
- # of subjects is large (especially in 1 & 3)

My agenda: Propose randomized experiment that respects subject welfare

Preview

I propose an experimental design that at once satisfies

1. randomly assigning treatment &
   generating at least as much causal info as usual RCT

2. as much as possible, assigning treatment to subjects with
   - better predicted treatment effects or
   - stronger preferences for the treatment

$$\updownarrow$$

Usual designs fail to satisfy (2)

Setting

$i_1, ..., i_n$: Experimental subjects
$t_0, t_1, ..., t_m$: Treatments
$c_t \in \mathbb{N}$: Treatment t's capacity (with $\Sigma_t c_t \geq n$)

w_{it}: Subject i's willingness to pay for treatment t with

$$w_{it} \geq w_{it'} \Leftrightarrow i \text{ weakly prefers } t \text{ over } t'$$

e_{ti}: t's predicted treatment effect for subject i with

$$e_{ti} \geq e_{ti'} \Leftrightarrow t \text{ is predicted weakly more effective for } i \text{ than for } i'$$

t_0: Placebo or control with normalization $e_{t_0 i} = w_{it_0} = 0$ for all i

Detail

Proposal

Definition (Experiment-as-Market a.k.a. EXaM)

1. In computer, distribute common artificial budget b to every subject
2. Find "price-discriminated market equilibrium"
   i.e., feasible treatment assignment prob.s $(p^*_{it})_{i,t}$ & prices $(\pi^*_{te})_{t,e}$ with

   - Utility maximization s.t. budget constraint: For all i,
     $$(p^*_{it})_t \in argmax_{\text{feasible } (p_{it})_t} \Sigma_t p_{it} w_{it} \text{ s.t. } \Sigma_t p_{it} \pi^*_{te_{ti}} \leq b$$
     (Ties are broken by uniformly mixing cheapest (p_{it})'s)

   - Effectiveness-discriminated treatment pricing: $\forall t \; \exists \alpha_t < 0$ & $\beta_t \; \forall e$,
     $$\pi^*_{te} = \alpha_t e + \beta_t$$
   - Meeting capacity constraint: $\Sigma_i p^*_{it} \leq c_t$ for all t
3. Draw final treatment assignment from $(p^*_{it})_{i,t}$.

Getting to the Goals

Proposition (Randomized Controlled Welfare Property)

Experiment-as-Market always exists & satisfies:

1. randomly assigning treatments,
   i.e., $p^*_{it} = p^*_{i't}$ for all t, i, i' with $(w_{it}, e_{ti})_t = (w_{i't}, e_{ti'})_t$
   generating at least as much causal info as usual RCT,
   i.e., any thing identified by vanilla RCT is also identified by EXaM
2. as much as possible, assigning treatment to subjects with
   - better predicted treatment effects or
   - stronger preferences for the treatment

   i.e., $\nexists$ assignment prob.s (p_{it}) with

   - $\Sigma_t p_{it} e_{ti} \geq \Sigma_t p^*_{it} e_{ti}$ (expected predicted effect) &
   - $\Sigma_t p_{it} w_{it} \geq \Sigma_t p^*_{it} w_{it}$ (expected willingness to pay)

   for all i with at least one strict inequality

Comparison with Existing Designs

Proposition

None of following designs has Randomized Controlled Welfare Property.

- Vanilla RCT

Designs respecting preferences:

- "Consent Trial" (Zelen 79, Angrist-Imbens 91, many medical RCT)
- "Selective Trial" (Chassang-Miquel-Snowberg 12)
- "Thompson Sampling" (Thompson 33, many web A/B tests)

Designs respecting predicted treatment effects:

- "Play-the-Winner Trial" (Wei-Durham 78, many medical RCT)
- "Adaptive Biased Coin Design" (Eisele 94, many medical RCT)
- "Empirical Welfare Maximization" (Manski 05, B-Dupas 12)

From Identification to Analyzing Data from EXaM

Recall EXaM makes treatments conditionally randomly assigned

Suggested Analysis Procedure

For simplicity assume only 1 treatment t_1 & control t_0.

1. Identify t_1's average effect conditional on $x_i \equiv (w_{it}, e_{ti})_t$ by

$$\underbrace{E(Y_i | i \text{ assigned } t_1, x_i)}_{\text{Observable}} - \underbrace{E(Y_i | i \text{ assigned } t_0, x_i)}_{\text{Observable}} \equiv (CATE)$$

2. Integrate ($) to get treatment effects of interest
   e.g. Average Treatment Effect$= \int (CATE) dF((x_i)$

Application in Progress

Setting:
Anti-malarial bed net pricing RCT in Kenya (Cohen-Dupas 10)

Embedding this setting into my theory:
t_1 & t_0: Free anti-malarial bed net & control

w_{it_1}: Subject i's willingness to pay for bed net
$\rightarrow$ Estimate it using C-D's randomization of bed net prices

$e_{t_1 i}$: Bed net's predicted treatment effect for subject i
$\rightarrow$ Proxy it by i's pre-RCT hemoglobin level (indicator of malaria)

Plan: Implement & compare Experiment-as-Market vs existing designs

Future Directions

Further econometric comparison of EAaM vs existing designs by...

- Identification (Blackwell-informativeness or identifiable parameters)?
- Estimation (Power or mean squared error)?

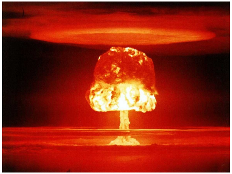
Extensions to...

- Dynamic (sequential) design?
- Uncertain & multi-dimensional predicted effects e_{ti}?
- Endogenous sample size n?

Using my framework to analyze other key aspects of RCT?
(e.g. pre-analysis plan, re-randomization, external validity, attrition)

Stepping Back: The Science Unto Death

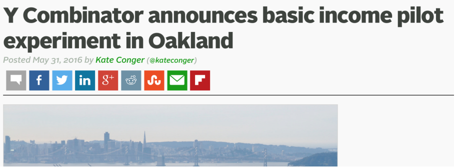
Science not only saves us but also kills us:



Atomic bomb

Biological weapon

Randomized experiment



Your Health Matters
OREGON
Health Study

Experiment-as-Market is step toward "best" allocation of lives & deaths created by randomization-driven science