Auctions and Market Design

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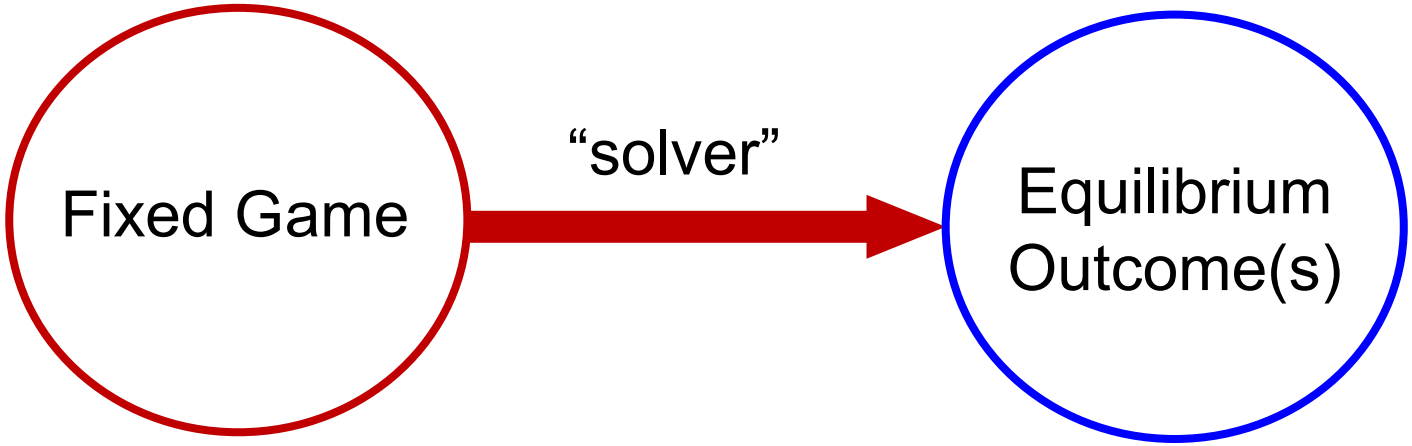
Today's Agenda

1) The Theory of Engineering Games

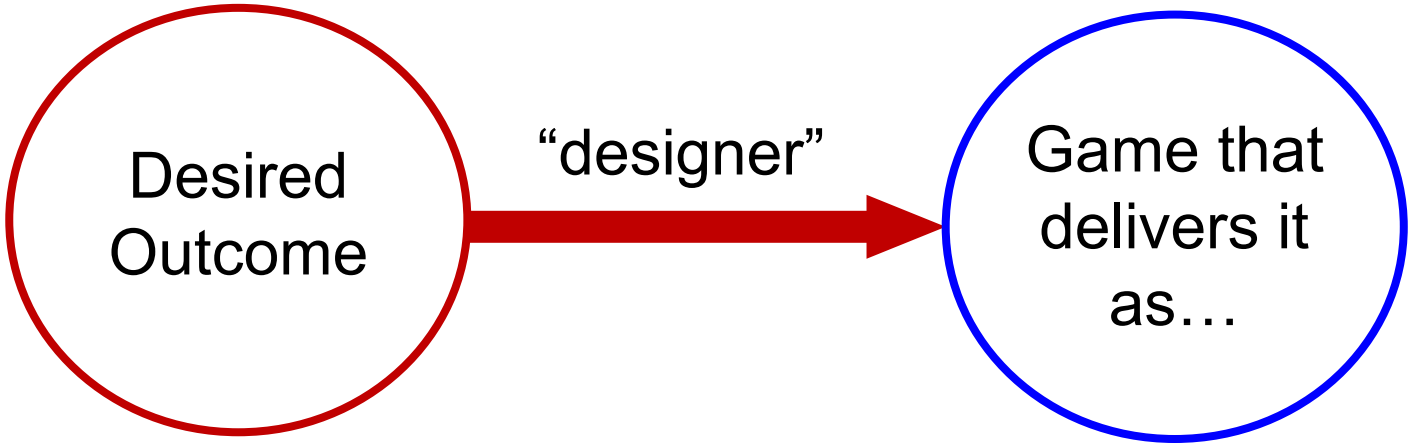
2) Designing Markets

3) Designing Auctions

Game Theory Approach



Mechanism Design Approach



… Nash equilibrium?
Dominant Strategy? …

Connected Applications

1. NYC Public Schools
2. Medical Residents
3. Spectrum auctions worldwide

- More applications later

NYC Schools pre-2004

- The goal: to place each student in the best school for him/her.
- The problem: you don't know students' preferences.

- Students submit a list of five schools. Schools select admits.
- The higher performing students get multiple offers.
- Nearly half the students (not a random sample) got no offers
- Thousands of unlucky teenagers wound up waiting through the summer only to be sent to schools they had not listed at all.
- Those schools were worse in all dimensions — including student achievement, graduation rate and college admissions — than the schools the students had asked to attend.

The Cost of Complexity

- The system encouraged safe, not ambitious, choices.
- Sought-after schools accepted only the applicants who had made them their first choice
- Students who aimed high and listed several such schools but were rejected by the first could blow their chances all the way down the list.
- Education Department's high school directory advised students to "determine what your competition is for a seat in this program"
- Now go figure out the Nash Equilibrium!!

NYC Schools Today

- Students list their **12** favorite schools, in order of preference
- The algorithm allows students to "propose" to their favorite school, which accepts or rejects the proposal.
- In the case of rejection, the algorithm looks to make a match with a student's second choice school, and so on.
- Students and schools connect only tentatively until the very end of the process.
- Unmatched/year from 31,000 to about 3,000.
- 50%→ top choice school and 85%→ top 3 choices
- Why?

Costs of a Decentralized Market

- Hospitals benefit from filling positions early
- Applicants benefit from delaying acceptance of positions.

➔ Offers were being made for positions up to 2 years in advance.

Efforts were made to delay the start of the process.

➔ Very short deadlines for responses by applicants

Opportunities for dissatisfaction … for both…

Centralized Admissions

- Each applicant ranks “acceptable” hospitals
- Each hospital ranks “acceptable” candidates
- Both can be (essentially) as long as you want.
- Rankings are submitted to a centralized system
- NRMP runs “the algorithm.”
- Gale and Shapley (1962): “College Admissions and the Stability of Marriage”

Deferred-Acceptance Algorithm

1. Each applicant “proposes” to his/her favorite hospital
2. The hospital rejects all applicants except its favorite one, but does not accept him/her just yet.
3. Each rejected applicant proposes to his/her second-choice hospital.
4. Each hospital again rejects all but its favorite applicant (possibly throwing the old favorite back in the pool).
5. The “proposals” continue until the process stops (i.e., no current favorite is replaced any more).

“List them in order of true preference”

- The resulting match is **stable**: no student-hospital pair that did not form would prefer to now break their current matches and get together.

  Why?

- It is a dominant strategy for an applicant to submit his / her true ranking.

  Why?

Several Difficulties

- Hospitals manipulation
  - "In the limit as the market becomes infinitely large, the proportion of employers who might profit from preference or capacity manipulation goes to zero (Kojima and Pathak, 2009)
- Couples
  - This problem does not go away with size
- …

Hospital Incentives

- It is not necessarily optimal for hospitals to rank applicants truthfully.
- Example: three students, (A B C); two hospitals (1 and 2).
- Student A prefers hospital 1 to 2
- Student B prefers hospital 2 to 1
- Student C prefers hospital 2 to 1
- Hospital 1 prefers student B to A to C
- Hospital 2 prefers student A to B to C

- If everyone reports truthfully, the students get their top choices in the first round. So the outcome is (A,1) and (B,2).
- If hospital 2 instead reports (A→C→B), then B and C apply to 2; hospital 2 keeps C and throws B in the pool. B applies to 1, which keeps him/her. Finally, A applies to 2, which keeps him/her.
- So the outcome is (A,2), and (B,1) which hospital 2 prefers.

Judicial Law Clerks (failed)

Current guidelines:

- Support a transparent recruitment process.
- Consider coordinating hiring activities court-wide.
- Use video conferencing when feasible.
- Do not require an applicant to accept an offer immediately without reasonable time to weigh it against other viable offers.
- Consider visiting law schools with a minority student population.

How well do you think this works?

Spectrum Auctions (FCC's Solution)

FCC auction

- *Game theory, long an intellectual pastime, came into its own as a business tool.*
- 1993: Congress authorizes FCC to auction spectrum for personal communications services.
- Goals: simplicity, efficiency, revenue, and diversity.
- Thousands of licenses varying in geographic coverage and amount of spectrum.
- Bidders: long-distance, local and cellular telephone companies.

FCC auction

- Auction format: **simultaneous ascending auction**
  - multiple licenses are open for bidding as long as there is some bidding on any one.
- Bidding for the PCS licenses is like playing a dozen hands of billion-dollar poker at once.
- Closing the gaps for clever bidders: details matter!
- Most important: activity rule (33-66-100)
- Secondary: bid increments.

FCC auction

- Why ascending (~English)?
  - *Winner's curse*
- Why simultaneous?
  - *Licenses are interdependent*
  - *Resale market*
  - *Gaming and holding-up*
- Still: jump-bidding and signaling.
- Total revenues > $60 billion (1994, ~$100B today)

What's the Connection?

- All licenses are open
- Bidders have preferences over licenses
- "Licenses" only care about $$$
- Standing high-bidder = current favorite
- Next round, could be replaced…
- … but has the option to "relocate"
- … or to reclaim its spot (up to the valuation)

Other Applications

- West Point Cadets
- Kidney Exchanges
- Course allocation
- Financial markets

High-Frequency Trading

- Clearing demand and supply for financial assets.
- Periodic auctions?
- "Instantaneous" order execution?

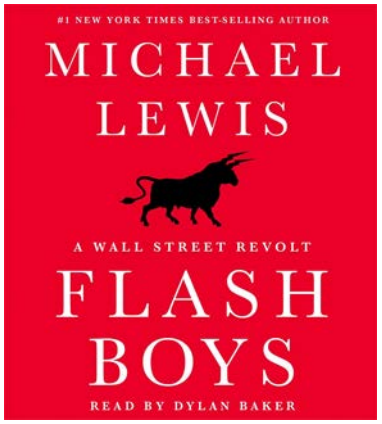
- Instantaneous: transparent, simple, dominant strategies, no "transaction risk," but …

- Perverse incentives: "dumb money" in the deal
- Overinvestment….


CHICAGO
DETROIT
CLEVELAND
NEW YORK
0
50 MILES
PITTSBURGH
PHILADELPHIA

Light Speed?

- In 2010, Spread Networks completed construction of a new high-speed fiber optic cable
- Connecting financial markets in New York and Chicago.
- Spread Networks' cable was nearly a straight line.
- Construction costs were $300 million.
- The result of this investment?
- Round-trip communication time between New York and Chicago was reduced . . .
  ….from **16** milliseconds to **13** milliseconds.
- Relativity bound is **> 7** milliseconds



Market Design: General Principles

- Transparency
- Strategy-proofness (dominance)
- Stability
- Simplicity
- Design elements complement each other

Next Week

- Games with Private information
  - Signaling
  - Communication
  - Poker

- R&D and project selection in Pharma

15.025 Game Theory for Strategic Advantage
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