Market Design: Theory and Applications

Introduction

Instructor: Itay Fainmesser

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- But bridge design also concerns metal fatigue, soil mechanics, and the sideways forces of waves and wind. Many questions concerning these complications can’t be answered analytically, but must be explored using physical or computational models.

- These complications, and how they interact with that part of the physics captured by the simple model, are the concern of the engineering literature. Some of this is less elegant than the simple model, but it allows bridges designed on the same basic model to be built longer and stronger over time, as the complexities and how to deal with them become better understood.
Market Design: The Economist as Engineer

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- Responsibility for detail requires the ability to deal with complex institutional features.
- Game theory, the part of economics that studies the “rules of the game,” provides a framework with which design issues can be addressed.
- But dealing with complexity will require new tools, to supplement the analytical toolbox of the traditional theorist.
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  - In designing new markets
  - In communicating results to policy makers
Overview

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- In recent years there have been some great advances in the theory of each of these, that brings them much closer together.
- A lot of these theoretical insights have come from the difficulties faced in designing complex labor markets and auctions (e.g. labor markets in which there may be two-career households, and auctions in which bidders may wish to purchase packages of goods).
Lessons from market failures (and successes)

- To achieve efficient outcomes, marketplaces need to make markets sufficiently:
  1. Thick: enough potential transactions available at one time
  2. Uncongested: enough time for offers to be made, accepted, rejected...
  3. Safe: safe to act straightforwardly on relevant preferences

Some kinds of transactions are repugnant... This can be an important constraint on market design.
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Examples

- Kidney exchange (thickness, congestion, incentives)
  - New England and Ohio (2005)
  - Is buying a kidney repugnant?

- Medical labor markets
  - NRMP in 1995 (thickness, congestion, incentives)
  - Gastroenterology in 2006 (thickness, incentives)
  - Is reneging on early acceptances repugnant?

- School choice systems:
  - New York City since Sept. 2004 (congestion & incentives)
  - Boston since Sept. 2006 (incentives)
  - Is exchanging priorities repugnant? (particularly sibling priorities)
  - SFUSD—presently underway

- American market for new economists
  - Scramble (thickness) March 2006
  - Signaling (congestion) December 2007
More Examples

- Online dating
- eBay and Amazon
- Google's internet ad auctions
- Landing slots in airports
  - a combinatorial auction?
Zooming through a matching example: matching doctors to first positions in U.S. and Canada

- 1995: redesign of the
  1. U.S. National Resident Matching Program (NRMP) (approx. 23,000 positions, 500 couples)
  2. Canadian Resident Matching Service (CaRMS) (1,400 Canadian medical grads, including 41 couples, 1,500 positions in 2005)

- 2005: redesign of the fellowship market for Gastroenterologists

- Contemporary issues in labor markets for Orthopedic surgeons, neuropsychologists, and law clerks for appellate judges.
Background to redesign of the medical clearinghouses

- 1900 - 1945: Unravelling of appointment dates

- 1945 - 1950: Chaotic recontracting - Congestion

- 1950 - 197x: High rates of orderly participation (95%) in the centralized clearinghouse

- 197x - 198x: Declining rates of participation (85%) particularly among the growing number of married couples

- 1995 - 1998: Market experienced a crisis of confidence with fears of substantial decline in orderly participation

Design effort commissioned - to design and compare alternative matching algorithms capable of handling modern requirements: couples, specialty positions, etc.

- Roth-Peranson clearinghouse algorithm adopted, and employed
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Stages and transitions observed in various markets

Stage 1: UNRAVELING
Offers are early, dispersed in time, exploding... No thick market

Stage 2: UNIFORM DATES ENFORCED
Deadlines, congestion

Stage 3: CENTRALIZED MARKET CLEARING PROCEDURES
What makes a clearinghouse successful or unsuccessful?

- A matching is “stable” if there aren’t a doctor and residency program, not matched to each other, who would both prefer to be.
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- Hypothesis: successful clearinghouses produce stable matchings.
- How to test this?
Gale, David and Lloyd Shapley [1962], Two-Sided Matching Model

- Men = \{m_1, m_2, \ldots, m_n\}  \quad \text{Women} = \{w_1, w_2, \ldots, w_p\}

- PREFERENCES (complete and transitive):
  - \( P(m_i) = w_3, w_2, \ldots, m_i, \ldots \quad [w_3 \succ_m w_2] \)
  - \( P(w_j) = m_2, m_4, \ldots, w_j, \ldots \)

- Outcomes = matchings: \( \mu : M \cup W \rightarrow M \cup W \) such that
  1. \( w = \mu(m) \) iff \( \mu(w) = m \), and
  2. either \( \mu(w) \) is in \( M \) or \( \mu(w) = w \), and
  3. either \( \mu(m) \) is in \( W \) or \( \mu(m) = m \)
Stable matchings

A matching $\mu$ is

- **Blocked by an individual** $k$ if $k$ prefers being single to being matched with $\mu(k)$, i.e.
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  - $k \succ_k \mu(k)$ ($\mu(k)$ is unacceptable).

A matching $\mu$ is stable if it isn't blocked by any individual or pair of individuals.

NB: A stable matching is efficient, and in the core, and in this simple model the set of (pairwise) stable matchings equals the core.
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### Stability as a criterion for a successful clearinghouse

<table>
<thead>
<tr>
<th>Market</th>
<th>Stable</th>
<th>Still in use (halted unraveling)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRMP</td>
<td>yes</td>
<td>yes (new design in ‘98)</td>
</tr>
<tr>
<td>Edinburgh (‘69)</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Cardiff</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Birmingham</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Edinburgh (‘67)</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Newcastle</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Sheffield</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Cambridge</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>London Hospital</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Medical Specialties</td>
<td>yes</td>
<td>yes (~30 markets, 1 failure)</td>
</tr>
<tr>
<td>Canadian Lawyers</td>
<td>yes</td>
<td>yes (Alberta, no BC, Ontario)</td>
</tr>
<tr>
<td>Dental Residencies</td>
<td>yes</td>
<td>yes (5) (no 2)</td>
</tr>
<tr>
<td>Osteopaths (&lt; ‘94)</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Osteopaths (≥ ‘94)</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Pharmacists</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Reform rabbis</td>
<td>yes (first used in ‘97-98)</td>
<td>yes</td>
</tr>
<tr>
<td>Clinical psych</td>
<td>yes (first used in ‘99)</td>
<td>yes</td>
</tr>
<tr>
<td>Lab experiments</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>(Kagel &amp; Roth QJE 2000)</td>
<td>no</td>
<td>no</td>
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</tbody>
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- Stage 0: if some preferences are not strict, arbitrarily break ties
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- Stage 1:

1. Each man proposes to his 1st choice (if he has any acceptable choices).
2. Each woman rejects any unacceptable proposals and, if she received more than one acceptable proposal, "holds" the most preferred and rejects all others.

Stage $k$:

1. Any man rejected at step $k$ makes a new proposal to its most preferred acceptable woman who hasn't yet rejected him. (If no acceptable choices remain, he makes no proposal.)
2. Each woman holds her most preferred acceptable offer to date, and rejects the rest.

When no further proposals are made, stop and match each woman to the man (if any) whose proposal she is holding.
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GS’s 2 Remarkable Theorems

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- Theorem 2 (GS) - When all men and women have strict preferences:
  1. There always exists an M-optimal stable matching (that every man likes at least as well as any other stable matching), and a W-optimal stable matching.
  2. The matching $\mu_M$ produced by the deferred acceptance algorithm with men proposing is the M-optimal stable matching. The W-optimal stable matching is the matching $\mu_W$ produced by the algorithm when the women propose.
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Incentives: many-to-one matching

- The 1952 National Internship Matching Program (NIMP) algorithm is equivalent to the hospital-proposing deferred acceptance algorithm, i.e. it produces the hospital-optimal stable matching (Roth ’84).

- Many-to-one matching (Roth, 1985):
  - No stable matching mechanism makes it a dominant strategy for all hospitals to state their true preferences.
  - The student-proposing deferred acceptance algorithm makes it a dominant strategy for all students to state their true preferences.

- Capacity manipulation (Sönmez, 1997): No stable matching mechanism makes it a dominant strategy for a hospital to always reveal its capacity.
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- **New theory** (Immorlica and Mahdian 2005, Kojima and Pathak 2009): as the market grows (in a very specific way), the proportion of hospitals that might profit from preference or capacity manipulation goes to zero in the student proposing deferred acceptance algorithm.
Some NRMP "match variations"

What makes the NRMP different from a simple market is that it has match variations of two kinds: variations which cause two positions to be linked to one another, and variations which cause the number of positions in a given program to change.

1. In the first category of variations are couples, who submit rank orders of pairs of programs and must be matched to two positions; and applicants who match to 2nd year positions and have supplemental lists which must then be consulted to match them to 1st year positions.
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2. In the second category are requests by residency programs to have an even or an odd number of matches, and reversions of unfilled positions from one program to another.
Going beyond the theory

- There is a large theoretical literature on two-sided matching, starting from GS.

Some theorems about simple markets:

1. The set of stable matchings is always nonempty.
2. The set of stable matchings always contains a "program optimal" stable matching, and an "applicant optimal" stable matching.
3. The same applicants are matched and the same positions are filled at every stable matching.

All of these theorems (and many more) have counterexamples in the complex medical market (or even if we just add couples).

Computational explorations can help to see how close an approximation the simple theory provides for the complex market.

Experiments can help to see how real people react to the market and which details are important.
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  2. The set of stable matchings always contains a "program optimal" stable matching, and an "applicant optimal" stable matching.
  3. The same applicants are matched and the same positions are filled at every stable matching.
Going beyond the theory

- There is a large theoretical literature on two-sided matching, starting from GS.
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- Experiments can help to see how real people react to the market and which details are important.
Zooming through an auction example: ad auctions

- 98% of Google’s and ~50% of Yahoo’s revenues
- The “future of advertising”
- Unusual auction rules: multiple units, but only one bid. Continuous time.
- Purely electronic market:
  - Good data, almost like a lab.
  - Flexibility to change auction rules from time to time
Search Results

Results 1 - 10 of about 17,200,000 for airfare - 0.04 sec. (About this page)

Also try: cheap airfare, discount airfare, international airfare, More...

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   www.travelzoo.com

   Priceline - Two Ways to Save on Airfare
   Choose from great low fares or name your own price and save even more.
   www.priceline.com

   Official Site of America West Airlines
   Find our lowest fares with bonus miles and no booking fees on americawest.com....
   www.americawest.com

   CheapAir.com: Airfare
Generalized Second-Price (GSP) auction

“[Google’s] unique auction model uses Nobel Prize-winning economic theory to eliminate ... that feeling that you’ve paid too much.”

First implemented by Google (2002), later adopted by Yahoo

- Each slot has a click-through-rate
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- Bidder $i$ has value $v_i$ for a click and can submit a bid $b_i$
- Bidders receive slots according to the ordering of their bids ($b_i$)
- Each bidder pay the bid of the next-highest bidder (per-click)
Nobel Prize-winning economic theory - Vickery’s 2nd price auction

- One good
Nobel Prize-winning economic theory - Vickery’s 2nd price auction

- One good
- Bidder $i$ has value $v_i$ for the good and can submit a bid $b_i$
Nobel Prize-winning economic theory - Vickery’s 2nd price auction

- One good
- Bidder $i$ has value $v_i$ for the good and can submit a bid $b_i$
- The highest bidder wins the object and pays the bid of the second highest bidder
Nobel Prize-winning economic theory - Vickery’s 2nd price auction

- One good
- Bidder $i$ has value $v_i$ for the good and can submit a bid $b_i$
- The highest bidder wins the object and pays the bid of the second highest bidder
- A dominant strategy: bid your value
‘Bid your value’ is not a dominant strategy under GSP

- **Idea:** sometimes, bidding below your true valuation can be profitable - you will get less traffic, but earn greater profits.
‘Bid your value’ is not a dominant strategy under GSP

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- **Example:** suppose that there are 3 bidders and 2 positions. Positions have click-through rates 100 and 80.

<table>
<thead>
<tr>
<th>bidder</th>
<th>bid</th>
<th>C’s valuation: $10</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$8</td>
<td>C bids $10, pays $8 → payoff ($10-$8)*100 =$200</td>
</tr>
<tr>
<td>B</td>
<td>$5</td>
<td>C bids $6, pays $5 → payoff ($10-$5)*80 =$400</td>
</tr>
</tbody>
</table>

$400>$200. So C should place a bid below its valuation.
Course structure (tentative) - many advanced topics

1. Matching Theory
2. NRMP design
3. Congestion in Matching Markets: the Market for Clinical Psychologists, College admission, AEA signaling, online dating
4. Unraveling: college football, the market for Gastroenterologists, the market for judicial clerks
5. Kidney exchange
6. School choice
7. Auction Theory
8. eBay vs. Amazon
9. Ad auctions
10. Combinatorial exchanges
11. Students’ presentations
Guests

Clayton Featherstone
http://www.people.hbs.edu/cfeatherstone/index.html

Francesco Decarolis
http://www.ssc.wisc.edu/~fdc/
Prerequisites

1. ECON 1110 or ECON 1130
2. MATH 0090 or equivalent
3. Background in Game Theory is a plus
4. Curiosity, open mindedness, and willingness to work hard
Required reading

- Many research papers
- Slides (when posted in advance)

Course website:
https://sites.google.com/a/brown.edu/itay-fainmesser/teaching/econ-1465
Assignments

- Problem sets
- Referee report (check out the guidelines on the course website)
- Final paper proposal (October 19)
- In class presentation (November 16 - December 7. Presentation slots will be assigned by the instructor)
- Final paper (December 14)

1. A review of a real-world market, with focus on the market rules, strengths and weaknesses of the existing design, and relevant academic literature.
2. A rigorous review of a question that is discussed in the academic literature on market design.
3. A research proposal that is related to Market Design (recommended only for students that plan to follow up with an honors thesis).
An idea for a term paper

- Here is the web site of the American Association of Colleges of Podiatric Medicine:
- They run a match, and here is the description of their algorithm:
- Is their algorithm equivalent to the hospital proposing deferred acceptance procedure?
- Does it produce the same matching, when it produces a matching?
- Does it always (for every preference profile) produce a matching?
- Is the description of the algorithm complete enough to be sure?