Who Gets What and Why?
The new economics of matching and market design

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Markets and marketplaces are ancient human artifacts, like language

And just as there are many natural languages, there are many kinds of markets and marketplaces

Not all markets are commodity markets
NY Stock Exchange
Matching markets

– In many markets, you care who you are dealing with, and prices don’t do all the work
– (In some matching markets, we don’t even let prices do any of the work...)
Stanford doesn’t raise tuition until just enough applicants remain to fill its seats

You can’t just show up for work at Google: you have to be hired
Matching markets are markets in which you can’t just choose what you want (even if you can afford it)—you also have to be chosen
Many markets fall in between pure commodity markets and pure matching markets

• New technologies make new kinds of markets possible
Matchmaking

New markets for traditional matchmaking
- eHarmony
- match.com
- okcupid
- coffee meets bagel
- tinder

New kinds of matchmaking
- upwork
- Uber
- Lyft
- Google
- Bing
- Facebook
- Taobao
- eBay
- UNOS
- Donate Life
- Eurotransplant
Airbnb

Additional fees apply. Taxes may be added.

Moderno y comod...
Private room · ★★★★☆ · 9 review

Dpto\Apto barrio...
Private room · ★★★★☆ · 31 review

Map of San Miguel, showing various Airbnb listings.
What do marketplaces do?

Airbnb, for example

- **Thickess**
  - Initially, Airbnb bought competitive rival web sites to get hosts and travellers (e.g. Crashpadder in England)
  - Now competitors are hotels
  - e.g. Sheraton Tucuman Hotel

- **Congestion**
  - Think of how much less convenient this hotel would be if you could only inquire about one room at a time...

- **Trust and Safety**
Matching Markets I’ve helped design:

• Medical labor markets
  – Medical Residents in the U.S.: National Resident Matching Program (NRMP)
  – Medical residents in Canada (CaRMS)
  – Medical fellowships
• Teacher assignment—Teach for America
• **School choice systems**: (no money changes hands, but preferences are important...)
• **Kidney exchange**
Not everyone likes a thick market

- Buyers like to see lots of sellers and sellers like to see lots of buyers, but not everyone wants to be on the market together with their competitors.
- So some markets start to move earlier and earlier, for example as employers try to hire (future) workers earlier than their competitors.
Markets can lose thickness when transactions happen too early

• “Unraveling”: from year to year some employers try to hire earlier than their competitors...

• American lawyers get their jobs more than a year before they graduate from law school
  – Law clerks for a judge
  – Summer associate positions at law firms

• American doctors
  – Today use a centralized clearinghouse, but used to be hired two years before graduation
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 centralized clearinghouse
- **197x-198x** DECLINING RATES OF PARTICIPATION (85%) particularly among the growing number of MARRIED COUPLES
- **1995-98** 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
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

Loss of thickness
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.
• Hypothesis: successful clearinghouses produce stable matchings.
• How to test this?
Stability and the medical match

• Roth (1984) showed that the algorithm adopted by the NRMP in 1951 produced stable matchings
<table>
<thead>
<tr>
<th>Market</th>
<th>Stable (rules are data!)</th>
<th>Still in use (halted unraveling)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRMP ’98</td>
<td>yes</td>
<td>yes (new design in...</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 (&gt; ’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 (Kagel&amp;Roth QJE 2000)</td>
<td>yes</td>
<td>yes.</td>
</tr>
<tr>
<td>(Kagel&amp;Roth QJE 2000)</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

Lab experiments fit nicely on the list, just more of a variety of observations that increase our confidence in the robustness of our conclusions, the lab observations are the smallest but most controlled of the markets on the list...
Gale-Shapley (1962) Deferred Acceptance Algorithm, with workers applying

• 1 a. Each worker applies to his/her top choice firm.
•   b. Each firm \( f \) with \( q \) positions holds the top \( q \) applications among the acceptable applications it receives, and rejects all others.
• k a. Any worker rejected at step \( k-1 \) makes a new application, to its most preferred acceptable firm that hasn’t yet rejected him/her. (If no acceptable choices remain, he/she makes no further offers.)
•   b. Each firm holds its \( q \) most preferred acceptable applications to date, and rejects the rest.
• STOP: when no further proposals are made, and match each firm to the workers (if any) whose applications it is holding.
GS’s 2 Remarkable Theorems

• **Theorem 1 (GS):** A stable matching exists for every marriage market.

• **Theorem 2 (GS):** When all firms and workers have **strict preferences**, the Worker-applying deferred acceptance algorithm produces the **W-optimal stable matching** $\mu_W$ (that every worker likes at least as well as any other stable matching). (The **Firm optimal stable matching** results when the firms make offers).
Incentives—how can we learn people’s preferences?

• Positive and negative results for finite markets without couples.
  – Dubins and Friedman (81), Roth (82): The deferred acceptance algorithm with workers proposing makes it a dominant strategy for workers to state their true preferences.
  – Roth (1982, 85): no stable mechanism makes it a dominant strategy for all agents to state their true preferences.
The complex world: Couples

• In the 1950’s, almost all American medical students were men
• By the 1970’s, about 10% were women
• Today 50% are women.
• Already in the 1970’s, it started to be observed that married couples did not use the match
• Recently about 2,000 graduates go through the match as couples (1,000 couples), out of about 17,000 American medical grads
An initial “couples algorithm” in the 1970’s

• Couples (after being certified by their dean) could register for the match as a couple.
  – They had to specify one member of the couple as the “leading member.”
  – They submitted a separate rank order list of positions for each member of the couple.

• The leading member went through the match as if single.

• The other member then had his/her rank order list edited to remove positions not in the ‘same community’ as the one the leading member had matched to.
  – Initially the NRMP determined communities; in a later version, when couples were still defecting, couples could specify this themselves.
But this didn’t work well for couples

• Why?

• The iron law of marriage: You can’t be happier than your spouse.

• Couples consume *pairs* of jobs. So an algorithm that only asks for their preference orderings over *individual* jobs can’t hope to avoid instabilities (appropriately redefined to include couples’ preferences)

• But even if we ask couples for their preferences over pairs of jobs, we may still have a problem: Roth (1984) observed that the set of stable matchings may be *empty* when couples are present.
  – Proof: by (counter)example. (Which was sufficient, when I didn’t have design responsibility...😊)
Why is the couples problem hard?

• Note first that the ordinary deferred acceptance algorithm won’t in general produce a stable matching (even when one exists, and even when couples state preferences over pairs of positions)
  – In the worker proposing algorithm, if my wife and I apply to a pair of firms in Boston, and our offers are held, and I am later displaced by another worker, my wife will want to withdraw from the position in which she is being held (and the firm will regret having rejected other applications to hold hers)
  – In the firm proposing algorithm, it may be hard for a couple to determine which offers to hold.
Stable Clearinghouses (those now using the Roth Peranson Algorithm)

NRMP / SMS:
Medical Residencies in the U.S. (NRMP)
Abdominal Transplant Surgery
Child & Adolescent Psychiatry
Colon & Rectal Surgery
Combined Musculoskeletal Matching Program (CMMP)
  • Hand Surgery
Medical Specialties Matching Program (MSMP)
  • Cardiovascular Disease
  • Gastroenterology (1986-1999; rejoined in 2006)
  • Hematology
  • Hematology/Oncology
  • Infectious Disease
  • Oncology
  • Pulmonary and Critical Medicine
  • Rheumatology
Minimally Invasive and Gastrointestinal Surgery
Obstetrics/Gynecology
  • Reproductive Endocrinology
  • Gynecologic Oncology
  • Maternal-Fetal Medicine
  • Female Pelvic Medicine & Reconstructive Surgery
Ophthalmic Plastic & Reconstructive Surgery
Pediatric Cardiology
Pediatric Critical Care Medicine
Pediatric Emergency Medicine
Pediatric Hematology/Oncology
Pediatric Rheumatology
Pediatric Surgery

Primary Care Sports Medicine
Radiology
  • Interventional Radiology
  • Neuroradiology
  • Pediatric Radiology
Surgical Critical Care
Thoracic Surgery
Vascular Surgery

Postdoctoral Dental Residencies in the United States
  • Oral and Maxillofacial Surgery
  • General Practice Residency
  • Advanced Education in General Dentistry
  • Pediatric Dentistry
  • Orthodontics

Psychology Internships in the U.S. and CA (1999)
Neuropsychology Residencies in the U.S. & CA (2001)
Osteopathic Internships in the U.S. (before 1995)
Pharmacy Practice Residencies in the U.S.
Articling Positions with Law Firms in Alberta, CA
Medical Residencies in CA (CaRMS)

*********************

British (medical) house officer positions
  • Edinburgh (1969)
  • Cardiff (197x)

New York City High Schools (2003); Boston Public Schools (2006), New Orleans, Washington DC, Denver...
Congested markets

• E.g. school assignment
School Choice—Bringing some market efficiency to an administrative process

• We don’t let prices do any of the work in assigning public school places
• Thickness is often not an issue (school is mandatory)
• But congestion and safety can be big problems
• Parents have some information about which schools would be good for their children
  – But not every school choice system makes it safe for them to share this information
School Choice: Different in different cities

• New York City high schools, 2003
  – School principals are active participants

• Boston public schools, in 2006
  – Boston Public Schools assigns capacities to schools and priorities to students at schools: principals play no role

• 2012: Denver, Washington DC, New Orleans, Newark
Old NYC High School Match
(Abdulkadiroglu, Pathak, Roth 2005)

**Overview:** *Congestion*

- Over 90,000 students enter high school each year in NYC
- Each was invited to submit list of up to 5 choices
- Each student’s choice list distributed to high schools on list, who independently make offers
- Only approx. 40% of students receive initial offers, the rest put on waiting lists—around 17,000 students received multiple offers--3 rounds to move waiting lists...
- Approx. 30,000 students assigned to schools not on their choice list, at the last minute
Issues in old (2002) system

• Schools saw rank orders
  Some schools took students’ rankings into account & considered only those that ranked their school first
• So it wasn’t safe for students and families to list their true preferences
• Students needed to strategize.
  – The 2002-03 Directory of the NYC Public High Schools: “determine what your competition is for a seat in this program”
Issues in old (2002) system

• **Principals concealed capacities**
  
  Deputy Chancellor (NYT 11/19/04):
  “Before you might have had a situation where a school was going to take 100 new children for 9th grade, they might have declared only 40 seats and then placed the other 60 children outside the process.”
The old \textbf{Boston} school match:

\begin{itemize}
  \item An \textit{immediate acceptance} system:
  \item Students have priorities at schools set by the school district
  \item Students entering grades K, 6, and 9 submit (strict) preferences over schools.
  \item \textbf{Then as many people as possible are assigned their first choice:}
    \begin{itemize}
      \item In priority order, everyone who can be assigned to his first choice is. Then 2\textsuperscript{nd} choices, etc.
    \end{itemize}
  \item \textbf{What could be wrong with a system like this?}
\end{itemize}
It wasn’t safe for families to list their true preferences

• If you fail to get the school you ranked first, the school you ranked second might already be filled with people who had ranked it first.

• You wouldn’t get in, even if you had the highest priority.
Basic Deferred Acceptance Algorithm for School Assignment

- Step 0.1: students (and, in NY, schools) privately submit preferences

- Step 1: Each student “applies” to her first choice. Each school tentatively assigns its seats to its applicants one at a time in their priority order. Any remaining applicants are rejected.

  ...

- Step k: Each student who was rejected in the previous step applies to her next choice if one remains. Each school considers the students it has been holding together with its new applicants and tentatively assigns its seats to these students one at a time in priority order. Any remaining applicants are rejected.

- The algorithm terminates when no student application is rejected, and each student is assigned her final tentative assignment.
Two mathematical results

• A matching is “stable” if there aren’t a doctor and residency program, not matched to each other, who would both prefer to be.

• Theorem (Gale and Shapley 1962): A stable matching exists for every marriage market.

• Theorem (Roth 1982): The deferred acceptance algorithm with workers proposing makes it safe for workers to state their true preferences.
NYC: First Year of Operation

- 3,000 students did not receive any school they chose
  - Compared to 30,000 who did not receive a choice school in the previous year
First 4 years: March 23, 2007
Results at end of Round 2
(Schools have learned to change their reporting of capacities)

School places that used to be withheld by principals returned over the first three years
Matching markets are important—and there are many more we need to understand

• In some of the most important markets, price doesn’t do all the work, and you can’t just choose what you want.
  – School choice, job markets, marriage... kidney exchange
  – **Refugee and migrant resettlement**
    • Refugees can’t just be sent to where they don’t want to go...
    • Refugees are precisely the people who move
      – Somalis in Maine (Lewiston and Portland)
      – Chinese and Spanish speakers in California
Migrants aren’t widgets
An American Nobel economist’s pressing advice for Europe.

By ALVIN E. ROTH | 9/3/15, 2:04 PM CET
Politics

What does the EU ‘tourist deal’ mean?

Britain’s new border is with Syria and Iraq

FACT

TUDTA?

Brüsszel egy városnyi illegális bevándorlót akar Magyarországra telepíteni.

NÉPSZAVAZÁS
2016. OKTÓBER 2.

BREAKING POINT
The EU has failed us all

TRUMP'S IMMIGRATION PLAN
- WALL ACROSS THE SOUTHERN BORDER
- DEPORTATION OF MILLIONS OF IMMIGRANTS IN THE U.S. ILLEGALLY
- END OF AUTOMATIC CITIZENSHIP FOR CHILDREN BORN TO FOREIGNERS IN U.S.
- PLAN MUST IMPROVE JOBS, WAGES AND SECURITY FOR ALL AMERICANS
Practical market design is always at least partly political

• New designs have to be adopted and implemented...
Market design as economic engineering

• Theory and practice
• Science and engineering aren’t exactly the same.
• But they complement each other—science guides the engineering, and engineering throws up new questions ahead of the science
  – They work on different time scales
Pythagoras’ Theorem: then and now
Engineering: not immutable

- Brooklyn Bridge (1883)
- Verrazano–Narrows Bridge (1964)
Market design is economic engineering

- Markets are human artifacts
- We need to build them, and to fix them when they’re broken
- We can learn a lot about economics by looking around us and seeing what works well, and what doesn’t work so well...
Later today 14:30 h.-16 h. Session on Organ and Blood Donations

Kidney exchange

- Donor 1
  - Blood type A
- Recipient 1
  - Blood type B
- Donor 2
  - Blood type B
- Recipient 2
  - Blood type A