Importance of Stability
Stages and transitions observed in various other markets with timing problems

**Stage 1: UNRAVELING**
Offers are early, dispersed in time, exploding...

**Stage 2: UNIFORM DATES ENFORCED**
Deadlines, congestion

**Stage 3: CENTRALIZED MARKET CLEARING PROCEDURES**
Unraveling (Roth and Xing ’94)

- **Stage 1** begins when the market comes into being (e.g. when a few hospitals begin offering internships, or when federal court clerkships are created by legislation) and the relatively few transactions are made without overt timing problems. By the middle of stage 1 the market has grown, and some appointments are being made rather early, with some participants finding that they don't have as wide a range of choices as they would like--students have to decide whether to accept early job offers or take a chance and wait for better jobs, and some employers find that not all of the students they are interested in are available by the time they get around to making offers. The trade journals start to be full of exhortations urging employers to wait until the traditional time to make offers, or at least not to make them any earlier next year than this year. Towards the end of stage 1, the rate of unraveling accelerates, until sometimes quite suddenly offers are being made so early that there are serious difficulties distinguishing among the candidates. There is no uniform time for offers to be made nor is there a customary duration for them to be left open, so participants find themselves facing unnaturally thin markets, and on both sides of the market a variety of strategic behaviors emerge, many of which are regarded as unethical practices. Various organizations concerned with the market may have proposed guidelines intended to regulate it, without notable success. As stage 1 ends, influential market participants are engaged in a vigorous debate about what can and should be done. From beginning to end, stage 1 may have covered a period of more than fifty years, or fewer than ten.
Causes and cures of unraveling

• Unraveling is one of the kinds of market failure that has often been corrected with appropriate clearinghouse design. But there’s still a lot that we don’t understand about its causes.
  – Unraveling results from *multiple* causes: you can only use time strategically in two directions (earlier and later), so there is going to be more than one reason to go early.
    • Avoiding congestion is one reason; early hiring may even be efficiency enhancing if there isn’t enough time to hire at an otherwise desirable late time. (This is one attraction of clearinghouses.)
“Forestalling”: unraveling in Medieval markets

• "Thus at Norwich no one might forestall provisions by buying, or paying 'earnest money' for them before the Cathedral bell had rung for the mass of the Blessed Virgin; at Berwick-on-Tweed no one was to buy salmon between sunset and sunrise, or wool and hides except at the market-cross between 9 and 12; and at Salisbury persons bringing victuals into the city were not to sell them before broad day."
Unraveling in Space

• "Besides injury through mere proximity, and anticipation in time, there might be damage due to interception of traffic..."

• "In 1233 Eve de Braose complained that Richard fitz-Stephen had raised a market at Dartmouth to the injury of hers at Totnes, as ships which ought to come to Totnes were stopped at Dartmouth and paid customs there. No decision was reached, and eight years later Eve's husband, William de Cantelupe, brought a similar suit against Richard's son Gilbert. The latter pleaded that his market was on Wednesday and that at Totnes on Saturday; but the jury said that the market at Dartmouth was to the injury of Totnes, because Dartmouth lies between it and the sea, so that ships touched there and paid toll instead of going to Totnes; and also that cattle and sheep which used to be taken to Totnes market were now sold at Dartmouth; the market at Dartmouth was therefore disallowed."

• Both quotes: Salzman, as quoted in Roth and Xing (1994)
History of the NRMP

- 1900-1945 UNRAVELLING OF APPOINTMENT DATES
- 1945-1950 CHAOTIC RECONTRACTING
- 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
- 198x-present Married couples return following changes in algorithm to accommodate couples and other kinds of match variations
- 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
- Roth- Peranson clearinghouse algorithm adopted, and employed
How do clearinghouses help stop unraveling?

They can establish a thick market at an efficient time.

• We’ve conjectured that stability plays a role in helping them do this successfully.
Priority matching (an unstable system)

- Edinburgh, 1967  
  No longer in use
  "  "  "  "  "  
- Newcastle 1970's  
  "  "  "  "  "  
- Sheffield  196x  
  "  "  "  "  "

In a priority matching algorithm, a 'priority' is defined for each firm-worker pair as a function of their mutual rankings. The algorithm matches all priority 1 couples and removes them from the market, then repeats for priority 2 matches, priority 3, etc.

E.g. in Newcastle, priorities for firm-worker rankings were organized by the *product* of the rankings, (initially) as follows: 1-1, 2-1, 1-2, 1-3, 3-1, 4-1, 2-2, 1-4, 5-1...
Priority matching (an unstable system)

• This can produce unstable matchings -- e.g. if a desirable firm and worker rank each other 4th, they will have such a low priority (4x4=16) that if they fail to match to one of their first three choices, it is unlikely that they will match to each other. (e.g. the firm might match to its 15th choice worker, if that worker has ranked it first...)

• After 3 years, 80% of the submitted rankings were pre-arranged 1-1 rankings without any other choices ranked. This worked to the great disadvantage of those who didn't pre-arrange their matches.
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?
Market | Stable | Still in use (halted unraveling)
--- | --- | ---
| NRMP | yes | yes (new design in ’98)
| Edinburgh ('69) | yes | yes
| Cardiff | yes | yes
| Birmingham | no | no
| Edinburgh ('67) | no | no
| Newcastle | no | no
| Sheffield | no | no
| Cambridge | no | yes
| London Hospital | no | yes
| Medical Specialties | yes | yes (~30 markets, 1 failure)
| Canadian Lawyers | yes | yes (Alberta, no BC, Ontario)
| Dental Residencies | yes | yes (5) (no 2)
| Osteopaths (< '94) | no | no
| Osteopaths (> '94) | yes | yes
| Pharmacists | yes | yes
| Reform rabbis | yes (first used in ‘97-98) | yes
| Clinical psych | yes (first used in ‘99) | yes

So stability looks like an important feature of a centralized labor market clearinghouse.
The need for experiments

• How to know if the difference between stable and unstable matching mechanisms is the key to success?
  – There are other differences between e.g. Edinburgh and Newcastle

• The policy question is whether the new clearinghouse needs to produce stable matchings (along with all the other things it needs to do like handle couples, etc.)
  – E.g. rural hospital question…
The need for Experiments

• Controlled experiments give us an opportunity to examine the different effect of the matching algorithms while holding everything else constant.

In addition, there are a lot of things that were simply unobservable in the field data.

• For example, what do the transitions look like?
• What happens when you introduce a centralized clearinghouse to a decentralized market in which appointment dates have unraveled to some inefficiently early time?
• How do successful transitions occur?
• How do unsuccessful transitions fail?

These questions are important, because there are lots of markets in transition (and as designers we need to manage the transition).
A matching experiment
(Kagel and Roth, QJE 2000)

- 6 firms, 6 workers (half "High productivity" half "low productivity")
- It is worth $15 plus or minus at most 1 to match to a high
- It is worth $5 plus or minus at most 1 to match to a low
- There are three periods in which matches can be made:-2, -1, 0.
- Your payoff is the value of your match, minus $2 if made in period -2, minus $1 if made in period -1
- Decentralized match technology: firms may make one offer at any period if they are not already matched. Workers may accept at most one offer. Each participant learns only of his own offers and responses until the end of period 0.
- After experiencing ten decentralized games, a centralized matching technology was introduced for period 0 (periods -2 and -1 were organized as before).
- Centralized matching technology: participants who are still unmatched at period 0 submit rank order preference lists, and are matched by a centralized matching algorithm.
- Experimental variable: Newcastle (unstable) or Edinburgh (stable) algorithm.
The (identical) instructions for each mechanism gave a description applicable to both algorithms:

“This centralized matching mechanism is designed to produce the best match possible, taking everyone's preferences into account. For example, if there is a matching which gives everyone his or her first choice, this will be the outcome of the matching mechanism. Even if this is not possible, if your first choice also ranks you first, you can be sure of being matched to your first choice. And the higher you rank some firm (if you are a worker) or some worker (if you are a firm), the greater your chance of being matched to that firm or worker. Finally, if you submit a rank order list that lists all six of your possible matches, and if each of your choices includes you on their rank order list, then you can be sure of being matched. That is, the matching mechanism can only match a firm and a worker each of whom lists the other on his rank order list, and if everyone includes all of his six options then the mechanism will leave no one unmatched.”
So the laboratory data reproduces the field data in terms of which algorithm is successful, but the successful algorithm gets adopted only gradually (something we couldn’t see in the field data).
Offers and acceptances

**High Firm Offer Rate: Period -2**

- Decentralized
- Mixed

**High Firm Offer Rate: Period -1**

- Decentralized
- Mixed

**High Worker Acceptance Rate: Period -2**

- Decentralized
- Mixed

**High Worker Acceptance Rate: Period -1**

- Decentralized
- Mixed
What do the experiments add to the field data?

• They show that stable versus unstable clearinghouse organization is important, in a controlled environment in which this is the only difference.

• Demonstrates robustness: we’ve now seen the same phenomena in markets ranging in size from 20,000+ participants, to hundreds, to half a dozen.

• Suggests that the asymmetry between firms and workers—and the ability to reject (or delay) unwanted offers—plays a critical role.
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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…
The Roth-Peranson algorithm is also used in other market clearinghouses since 1998

- Postdoctoral Dental Residencies in the United States
- Psychology Internships in the United States and Canada
- Neuropsychology Residencies in the United States and Canada
- Osteopathic Internships in the United States
- Pharmacy Practice Residencies in the United States
- Articling Positions with Law Firms in Alberta, Canada
NRMP also runs Fellowship matches through the Specialties Matching Service (SMS) (using the Roth-Peranson algorithm since 1998)

- Abdominal Transplant Surgery (2005)
- Combined Musculoskeletal Matching Program (CMMP)
  - Hand Surgery (1990)
- Medical Specialties Matching Program (MSMP)
  - Cardiovascular Disease (1986)
  - Hematology (2006)
  - Hematology/Oncology (2006)
  - Infectious Disease (1986-1990; rejoined in 1994)
  - Oncology (2006)
  - Pulmonary and Critical Medicine (1986)
  - Rheumatology (2005)

- Obstetrics/Gynecology
  - Reproductive Endocrinology (1991)
  - Gynecologic Oncology (1993)
  - Maternal-Fetal Medicine (1994)
  - Female Pelvic Medicine & Reconstructive Surgery (2001)
- Pediatric Cardiology (1999)
- Pediatric Critical Care Medicine (2000)
- Pediatric Emergency Medicine (1994)
- Pediatric Hematology/Oncology (2001)
- Pediatric Rheumatology (2004)
- Pediatric Surgery (1992)
- Primary Care Sports Medicine (1994)
- Radiology
  - Interventional Radiology (2002)
  - Neuroradiology (2001)
  - Pediatric Radiology (2003)
- Surgical Critical Care (2004)
- Thoracic Surgery (1988)