Nemmers Conference in honor of Paul Milgrom

Panel Discussion

What is the relationship between theory and market design?

Al Roth, Harvard University

Theory and design interact, differently each time

- Labor Market clearinghouses
  - **NRMP** 1995 (Roth and Peranson)
  - **Gastroenterology** decentralized market rules (with Niederle, Proctor)
- School choice: **NYC** 2003, **Boston**, 2006, **SF** underway (with Abdulkadiroglu, Featherstone, Niederle, Pathak, Sonmez)
- Kidney Exchange 2004- (with Sonmez, Unver, many doctors)
- Market for new Ph.D. economists (signaling and scramble) 2006- (with Coles, Niederle, AEA committee)

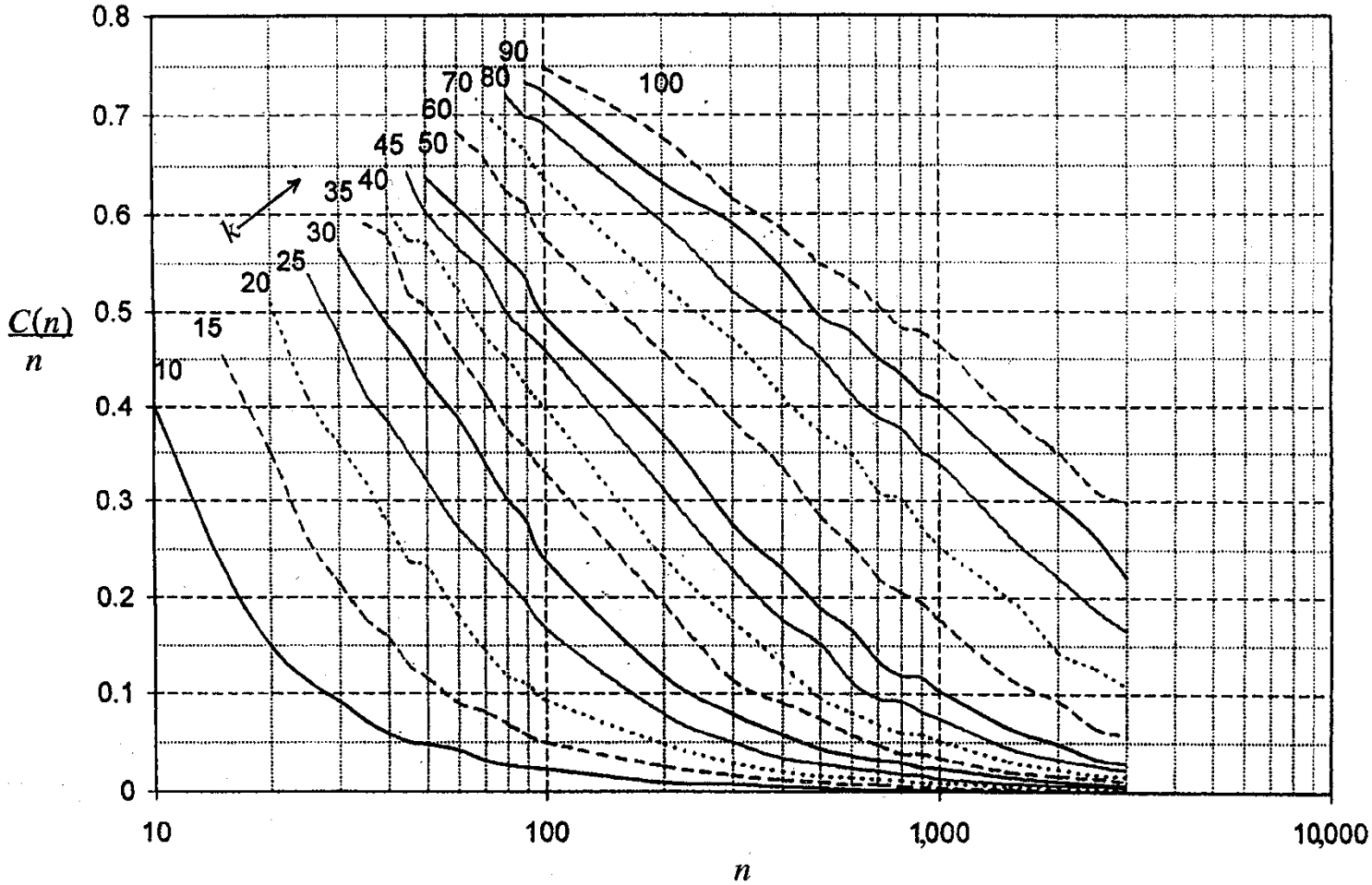
National Resident Matching Program

- Pre-existing theory: two sided matching
  - Stability: Gale and Shapley ’62
    - **Stable matchings** exist for simple many to one two-sided matching models, and there is an optimal stable matching for each side
    - **Rural hospital theorem** (Roth ‘86): hospitals that don’t fill all their positions get exactly the same residents at every stable matching
  - **Incentives** (Roth ‘85): In a many to one matching model, the student optimal stable mechanism is strategy proof for students. No stable mechanism is strategy proof for hospitals.

New issues

- Couples and other complementarities
  - Can make the core empty (Roth, 1984)
  - But seldom seem to in large markets
- Computational discoveries about large markets (Roth and Peranson '99)

But the set of stable matchings is small if the market grows but the number of applications per person does not…



New theory

- Subsequent new theory for large markets
  - Immorlica and Mahdian (2005)
  - Kojima and Pathak (2009)

Stable Clearinghouses (those now using the Roth Peranson Algorithm)

NRMP / SMS:

Medical Residencies in the U.S. (NRMP) (1952)
Abdominal Transplant Surgery (2005)
Child & Adolescent Psychiatry (1995)
Colon & Rectal Surgery (1984)
Combined Musculoskeletal Matching Program (CMMP)
- Hand Surgery (1990)

Medical Specialties Matching Program (MSMP)
- Cardiovascular Disease (1986)
- **Gastroenterology (1986-1999; rejoined in 2006)**
- Hematology (2006)
- Hematology/Oncology (2006)
- Infectious Disease (1986-1990; rejoined in 1994)
- Oncology (2006)
- Pulmonary and Critical Medicine (1986)
- Rheumatology (2005)

Minimally Invasive and Gastrointestinal Surgery (2003)
Obstetrics/Gynecology
- Reproductive Endocrinology (1991)
- Gynecologic Oncology (1993)
- Maternal-Fetal Medicine (1994)
- Female Pelvic Medicine & Reconstructive Surgery (2001)

Ophthalmic Plastic & Reconstructive Surgery (1991)
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)
Vascular Surgery (1988)

Postdoctoral Dental Residencies in the United States
- Oral and Maxillofacial Surgery (1985)
- General Practice Residency (1986)
- Advanced Education in General Dentistry (1986)
- Pediatric Dentistry (1989)
- Orthodontics (1996)

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. (1994)
Articling Positions with Law Firms in Alberta, CA(1993)
Medical Residencies in CA (CaRMS) (before 1970)

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

New York City High Schools (2003)
Boston Public Schools (2006)

Unravelling in gastroenterology

- How to help participants wait for a clearinghouse, in an unravelled, low-trust/ low enforcement market.
- Niederle, Muriel and Alvin E. “Market Culture**: How Rules Governing Exploding Offers Affect Market Performance**," *American Economic Journal: Microeconomics*, 1, 2, August 2009, 199-219..

School Choice

- Existing theory: stability, deferred acceptance algorithm and top trading cycles, mostly strict preferences (which made sense for labor markets)
- New theory: indifferences
  - Aytek Erdil and Haluk Ergin, **What's the Matter with Tie-breaking? Improving Efficiency in School Choice**, *American Economic Review*, 98(3), June 2008, 669-689.
  - Abdulkadiroğlu, Atila, Parag A. Pathak, and Alvin E. Roth, "**Strategy-proofness versus Efficiency in Matching with Indifferences**: Redesigning the NYC High School Match," *American Economic Review*, forthcoming.

AEA: market for new economists

- Signaling to help coordination of a congested interview process
- contemporaneous theory; Coles, Kushnir, Niederle

Kidney exchange

- Co-evolving theory and practice
- Fancy graph theory
- NP complete optimization problems
- Simple cost benefit analysis

Kidney exchange clearinghouse design

Roth, Alvin E., Tayfun Sönmez, and M. Utku Ünver, "**Kidney Exchange**," *Quarterly Journal of Economics*, 119, 2, May, 2004, 457-488.

_____started talking to docs_____

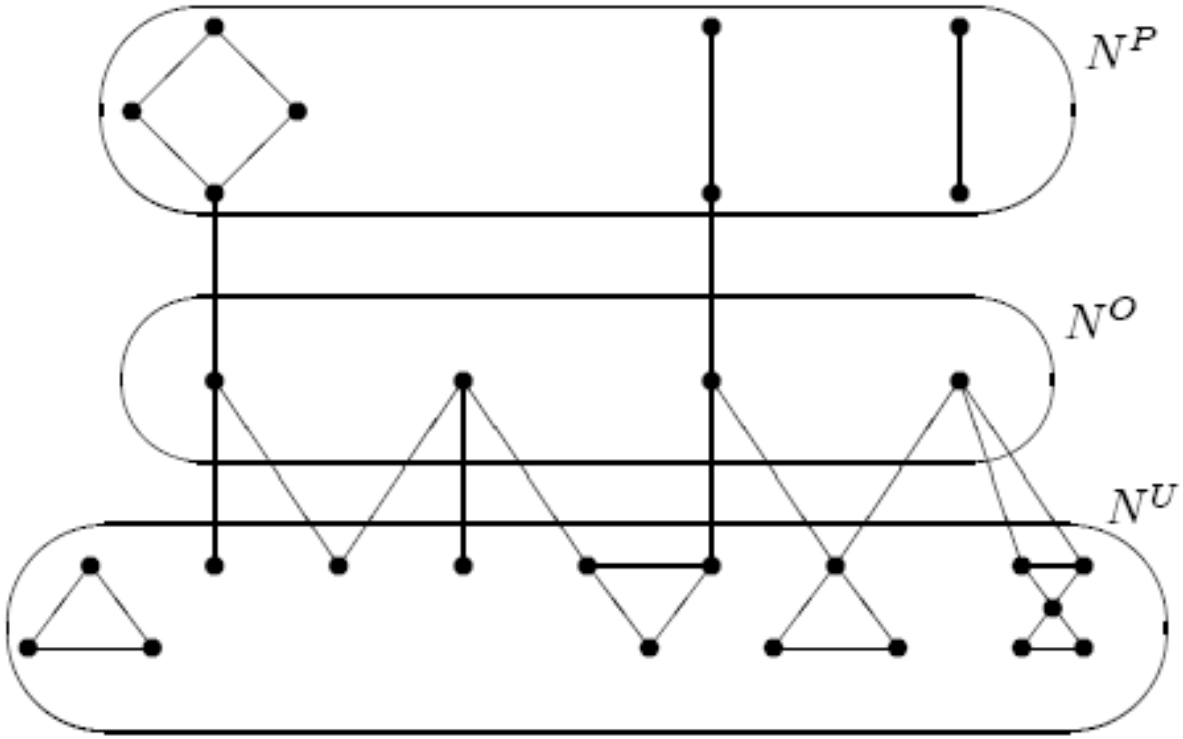
____ "**Pairwise Kidney Exchange**," *Journal of Economic Theory*, 125, 2, 2005, 151-188.

___ "A Kidney Exchange Clearinghouse in New England**,**" *American Economic Review,* Papers and Proceedings, 95,2, May, 2005, 376-380.

_____ "**Efficient Kidney Exchange**: Coincidence of Wants in Markets with Compatibility-Based Preferences," *American Economic Review*, June 2007, 97, 3, June 2007, 828-851

Incentive Constraint: 2-way exchange involves 4 *simultaneous* surgeries.

Gallai-Edmonds Decomposition



Incompatible patient-donor pairs in long and short supply in a sufficiently **large** market

- Long side of the market— (i.e. some pairs of these types will remain unmatched after any feasible exchange.)
  - hard to match: looking for a harder to find kidney than they are offering
  - O-A, O-B, O-AB, A-AB, and B-AB,
  - |A-B| > |B-A|
- Short side:
  - Easy to match: offering a kidney in more demand than the one they need.
  - A-O, B-O, AB-O, AB-A, AB-B
- Not hard to match whether long or short
  - A-A, B-B, AB-AB, O-O
- All of these would be different if we weren't confining our attention to *incompatible* pairs.

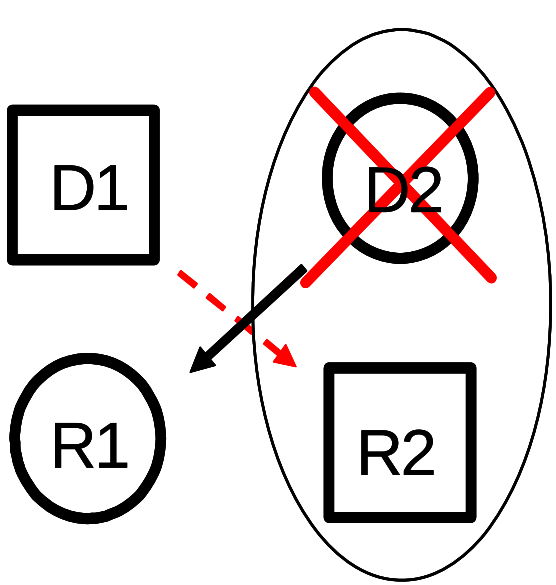
3 pairs is almost efficient for exchanges

- **Theorem** (Roth Sonmez Unver, AER 07) : in a sufficiently large market every efficient matching of patient-donor pairs can be carried out in exchanges of no more than 4 pairs.

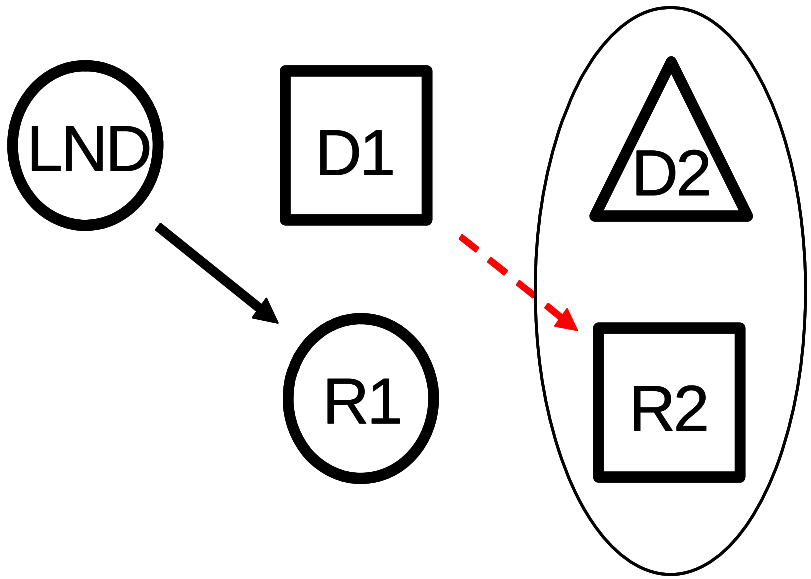
Saidman, Susan L., Alvin E. Roth, Tayfun Sönmez, M. Utku Ünver, and Francis L. Delmonico, "Increasing the Opportunity of Live Kidney Donation By Matching for **Two and Three Way Exchanges**," *Transplantation*, 81, 5, March 15, 2006, 773-782.

Roth, Alvin E., Tayfun Sönmez, M. Utku Ünver, Francis L. Delmonico, and Susan L. Saidman, "Utilizing **List Exchange and Undirected Donation through "Chain" Paired Kidney Donations**," *American Journal of Transplantation*, 6, 11, November 2006, 2694-2705.

Cost benefit analysis: Non-simultaneous altruistic donor chains (reduced risk from a broken link)



A. Conventional 2-way Matching



B. NEAD Chain Matching

If altruistic donor chains don't need to be simultaneous, they can be extended to be long…if the 'bridge donors' are properly identified.

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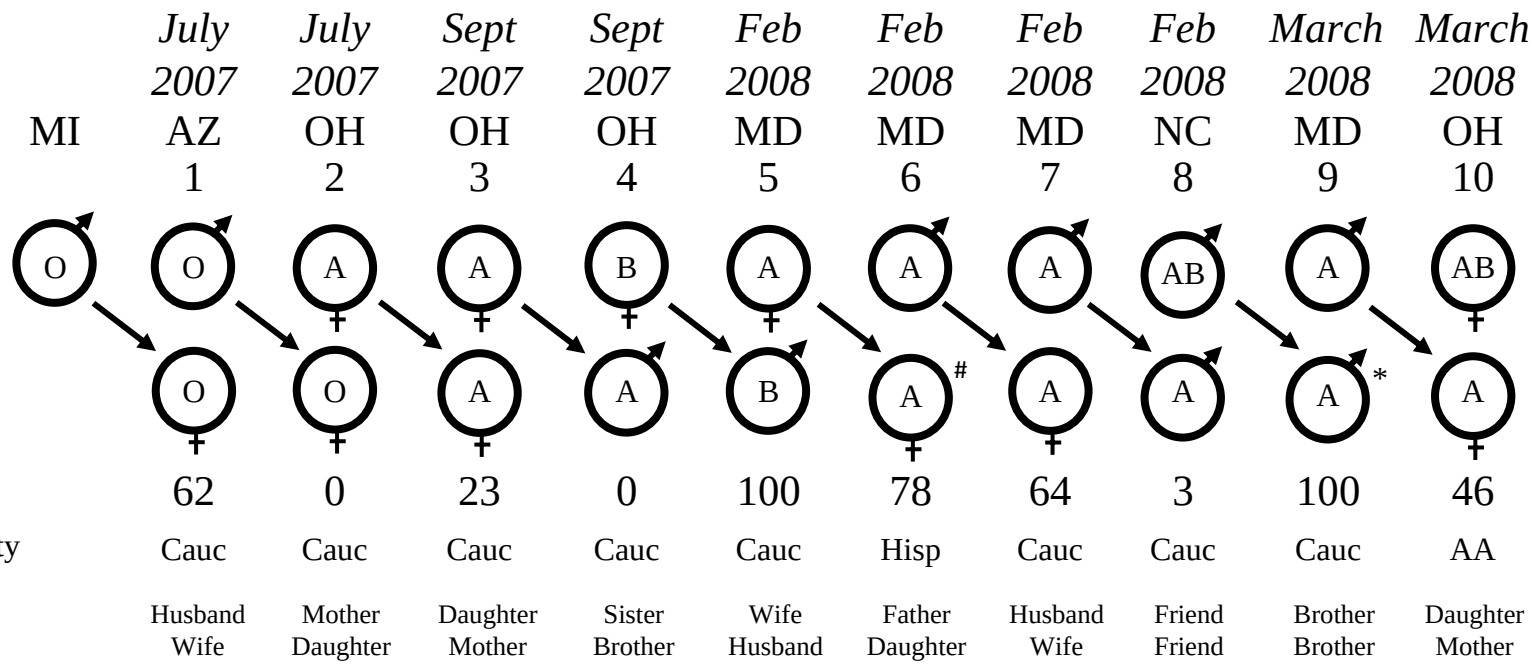
A Nonsimultaneous, Extended, Altruistic-Donor Chain

Michael A. Rees, M.D., Ph.D., Jonathan E. Kopke, B.S., Ronald P. Pelletier, M.D., Dorry L. Segev, M.D., Matthew E. Rutter, M.D., Alfredo J. Fabrega, M.D., Jeffrey Rogers, M.D., Oleh G. Pankewycz, M.D., Janet Hiller, M.S.N., Alvin E. Roth, Ph.D., Tuomas Sandholm, Ph.D., M. Utku Ünver, Ph.D., and Robert A. Montgomery, M.D., D.Phil.

SUMMARY

We report a chain of 10 kidney transplantations, initiated in July 2007 by a single altruistic donor (i.e., a donor without a designated recipient) and coordinated over a period of 8 months by two large paired-donation registries. These transplantations involved six transplantation centers in five states. In the case of five of the transplantations, the donors and their coregistered recipients underwent surgery simultaneously. In the other five cases, "bridge donors" continued the chain as many as 5 months after the coregistered recipients in their own pairs had received transplants. This report of a chain of paired kidney donations, in which the transplantations were not necessarily performed simultaneously, illustrates the potential of this strategy.

The First NEAD Chain (Rees et al.)



* This recipient required desensitization to Blood Group (AHG Titer of 1/8).

This recipient required desensitization to HLA DSA by T and B cell flow cytometry.

The state of the art of theory and market design?

- Can be summarized in two words:

Paul Milgrom