Decentralized Matching with Aligned Preferences

Muriel Niederle   Leeat Yariv

May 7, 2011

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- Many real matching markets are decentralized: U.S. college admissions, market for law clerks, junior economists, etc.
- One aspect of decentralized markets we will focus on is the inherent dynamic interaction

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- Identify conditions under which decentralized markets and centralized markets produce identical outcomes
- Part of a general theoretical question - are there non-cooperative foundations for cooperative solutions (e.g., the core)?

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  - preference distribution
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- Analyze equilibrium outcomes of this game
  - **Implementability:** sufficient preference richness allows stability
  - **Uniqueness:** complete information + aligned preferences + refinement

Related Literature

Empirical studies

- Avery, Jolls, Posner, and Roth (2001), Niederle and Roth (2003, 2007), Echenique and Yariv (2011), Fox (2010)

Analysis of dynamic games (mostly complete information, restricted strategy spaces)

- Outcomes: Blum, Roth, and Rothblum (1997), Haeringer and Wooders (2009), Diamantoudi, Miyagawa, and Xue (2007)
- Implementation: Alcade (1996), Alcalde, Pérez-Castrillo, and Romero-Medina (1998), Alcalde and Romero-Medina (2000)

Strategic matching in markets with frictions

- Burdett and Coles (1997), Eeckhout (1999), Shimer and Smith (2000)

General Set Up

Economies and Preferences

- A market is a triplet $\mathcal{M} = (\mathcal{F}, \mathcal{W}, U)$
  - Firms: $\mathcal{F} = \{1, ..., F\}$
  - Workers: $\mathcal{W} = \{1, ..., W\}$
  - Match utilities:

$$U = \left\{ \underbrace{u^f_{ij}}_{\textbf{firm } i's \text{ utility from matching with } j}, \underbrace{u^w_{ij}}_{\textbf{worker } j's \text{ utility from matching with } i} \right\}$$

- One-to-one matching with non-transferrable utilities
- Strict preferences, we say worker j is *unacceptable* to firm i if $u^f_{i\varnothing} > u^f_{ij}$. Similarly for workers.
- $u^f_{i\varnothing}, u^w_{\varnothing j} > 0$ for all i, j.

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- An economy is a quadruplet $(\mathcal{F}, \mathcal{W}, \mathcal{U}, G)$
  - Firms: $\mathcal{F} = \{1, ..., F\}$
  - Workers: $\mathcal{W} = \{1, ..., W\}$
  - $\mathcal{U}$ is a *finite* collection of match utilities
  - G is a distribution over $\mathcal{U}$

Uniqueness

Assume every market $\mathcal{M} = (\mathcal{F}, \mathcal{W}, U)$ has a **unique stable matching** μ_M (sidestep coordination).

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- $t = 1, 2, ...$: two stages as follows

  Stage 1: firms simultaneously decide whether and to whom to make an offer. Unmatched firm can have at most one offer out.

  Stage 2: each worker j who has received an offer from i can accept, reject, or hold the offer.

- Once an offer is accepted, worker j is matched to firm i irreversibly.

Payoffs

- Firm i matched to worker j at time $t \longrightarrow$ payoffs $\delta^t u_{ij}^f$ and $\delta^t u_{ij}^w$, where $\delta \leq 1$ is the *market discount factor*. Unmatched agents receive 0.

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- To ease getting stable matching: focus on high δ

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Information

- $t = 0$: underlying structure (particularly G) is common knowledge. Two information structures:
  - **Complete Information**: all agents are informed of realized U.
  - **Private Information:** each agent is informed of their own realized match utilities.

Market Monitoring

- Firms and workers observe receival, rejection, and deferral only of own offers. When an offer is accepted, the whole market is informed of the match. Similarly, when there is market exit.

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- **Equilibrium notion:** Bayesian Nash equilibrium.

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  - Preference distribution (unique stable outcome)
  - Information: complete or private
- **Assumptions making stability easier to achieve**:
  - In any market, unique stable matching
  - High discount factor

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But there can be other (unstable) equilibrium outcomes...

Example: Multiplicity

$$\begin{array}{ll} \mathbf{F1}: & W2 \succ \mathbf{W1} \succ W3 \\ \mathbf{F2}: & W1 \succ \mathbf{W2} \succ W3 \\ \mathbf{F3}: & W1 \succ W2 \succ \mathbf{W3} \end{array}, \quad \begin{array}{ll} \mathbf{W1}: & \mathbf{F1} \succ F3 \succ F2 \\ \mathbf{W2}: & \mathbf{F2} \succ F1 \succ F3 \\ \mathbf{W3}: & F1 \succ \mathbf{F3} \succ F2 \end{array}.$$

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$$\mu_M = \begin{array}{ccc} F1 & F2 & F3 \\ W1 & W2 & W3 \end{array}, \quad \tilde{\mu} = \begin{array}{ccc} F1 & F2 & F3 \\ W2 & W1 & W3 \end{array}.$$

μ_M unique stable matching, can implement $\tilde{\mu}$.

In "sub-market" without $(F3, W3)$, multiple stable matchings:

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Stage 1 : $F3$ and $W3$ match, Stage 2: follow $\tilde{\mu}$.

$\tilde{\mu}$ induces the firm preferred stable matching in stage 2.

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- *When preferences are aligned, there is a unique stable matching* μ_M (cf. Clark, 2006).

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Intuition: Construct stable match recursively:

- top match of entire market must be part of stable match
- then top match of remaining market must be part of stable match

Aligned Preferences – Uniqueness

Proposition 2 (Complete Information - Alignment): *With complete information, when all supported preferences are aligned, the stable matching of each realized market is the unique Nash equilibrium outcome surviving iterated elimination of weakly dominated strategies.*

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- Stable matching is always an equilibrium outcome
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In decentralized markets: Firms can condition their second round offers on the first period matches, and more outcomes can be achieved in equilibrium.

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- **Transmission of information**:
  - Match formation or market exit
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  - Reacting to offers: acceptance, rejection, or holding
- For the rest of the talk, assume preferences are aligned.

Aligned Economies: No Frictions

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- Firms make offers to workers according to their ordinal preferences.
- Firms exit when all acceptable workers rejected them or exited.
- Workers hold most preferred acceptable offer, accept an offer from most preferred unmatched firm.
- Workers exit as soon as no acceptable firm is unmatched.

Proposition 3: *Suppose preferences are aligned, and $\delta = 1$. Deferred acceptance strategies constitute a Bayesian Nash equilibrium in weakly undominated strategies and yield the stable matching μ_M.*

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Note: Alignment – In every period some information becomes public.

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	$W1$	$W2$
$F1$	3	**6**
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- $F2$ knows $W1$ will accept an offer immediately.
- $F2$ will not make an offer to $W2$.

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- Suppose all follow deferred acceptance, with appropriate skipping.

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- Firm 2 makes an offer to Worker 2 in U_1, to Worker 1 in U_2
- Firm 1 can try to speed up the process by making an offer to Worker 1 in period 1
- Suppose 1 accepts a period 1 offer (add more markets...).

$$\textcolor{red}{p} : U_1 = \begin{array}{|c|c|c|}\hline & W1 & W2 \\ \hline F1 & \mathbf{3} & 6 \\ \hline F2 & 4 & \mathbf{7} \\ \hline \end{array}, \quad \textcolor{red}{1\text{-}p} : U_2 = \begin{array}{|c|c|c|}\hline & W1 & W2 \\ \hline F1 & 3 & \mathbf{6} \\ \hline F2 & \mathbf{4} & 5 \\ \hline \end{array}.$$

When Firm 1 observes $(3, 6)$,

- Follows deferred acceptance $\Rightarrow$ payoff: $6(1-p) + 3p\delta$
- Deviate to an immediate offer to $W1$ $\Rightarrow$ payoff: $6(1-p)\delta + 3p$
- If $p > 2/3$ the deviation is profitable.

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Main Issue: The timing of offers in and of itself is informative

Simply Use Gale-Shapley?

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  1. How do workers know when to accept an offer (the market ends)?
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  2. Do agents have incentives to operate in order of their preference list (that leads to stability...)?
     - The example illustrated one incentive issue: the incentive to *speed up* matches.
     - Another issue: the incentive to *alter* final match.

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    2. Do agents have incentives to operate in order of their preference list (that leads to stability...)?
        - The example illustrated one incentive issue: the incentive to *speed up* matches.
        - Another issue: the incentive to *alter* final match.
- For 'deferred acceptance' to be incentive compatible, learning must be limited:
    - 'Rich' economies...

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- The support of match utilities is countable (say, integers);
- Generation by a two-stage randomization.

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Corollary: *In a rich economy, for sufficiently high δ, the stable match is implementable through a Bayesian Nash equilibrium in strategies that are not weakly dominated.*

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Corollary: *In a rich economy, for sufficiently high δ, the stable match is implementable through a Bayesian Nash equilibrium in strategies that are not weakly dominated.*

In general: Can define 'learning free' economies that rule out possibility to speed up or alter matches using deferred acceptance-type of strategies.

How Alignment Helps

- At every stage some information becomes public.
- No incentive to reject a firm in order to trigger a chain leading to a superior offer.

Conclusions

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- With **complete information**, the unique stable match is always implementable
    - generally not uniquely
- With **incomplete information,**
    - Without frictions ($\delta = 1$), can always implement the stable matching
    - With frictions, implementability for sufficiently high δ when the econom(Wic9cm10d 9cm10d enougm10d 0) Tle8(ys)r1(s)-

Extensions

Some market attributes that make achieving stability more difficult:

- General preferences

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- Wages

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- Wages
- Exploding offers

The End