Signaling

October 19, 2011

Congestion in labor markets

- We have seen in many decentralized markets: Congestion implies that it is not safe for participants to reveal their true preferences, that is:
  - firms may not make offers to participants in the order in which they rank them in terms of desirability of the candidate
  - Workers may not be able to wait for the best offer available
- In many markets with congestion:
  - Applicants try to signal that they would like accept an offer from a certain place
  - Employers pay attention to how likley it is a participant would accept an offer

- Simple model of Preference Signaling
- Application to the Economics Job Market
- Empirical Evidence that sending a signal imporves the chances of Success

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  2. **Preference signaling**

Signaling in practice

Credible Signaling in some Markets with Congestion

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  - several "virtual roses" (www.cupid.com)
  - Lee, Niederle, Kim and Kim (2010)
- College admissions, Avery et al (2003), Avery and Levin (2009)
  - early action
  - signal enthusiasm

Signaling in practice

These examples all share three important features.

1. Substantial frictions lead to market congestion:
   - employers cannot give full attention to all possible candidates
2. Applicants are ready to signal preferences over employers.
   - The markets found ways to make signals credible
3. Employers value this preference information and are prepared to act on it.

Coles, Kushnir and Niederle (2011): Preference Signaling in Matching Markets

Model a decentralized congested market without transfers:

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We develop a model that can account for the three stylized facts.

- What is the impact of a signaling mechanism?
- When does a signaling mechanism have the highest impact?

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- Costless signaling
  - Crawford and Sobel (1982)

A simple example

How preference signaling can work:

- 2 firms and 2 workers

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- Preferences of firms are i.i.d. and
  - $Pr(w_1 \succ_{f_j} w_2) = \Pr(\ w_2 \succ_{f_j} w_1) = \frac{1}{2}$

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  - $Pr(f_1 \succ_{w_i} f_2) = \Pr(\ f_2 \succ_{w_i} f_1) = \frac{1}{2}$
- Cardinal utility of agent a
  - top choice $\Rightarrow 1$
  - second choice $\Rightarrow x$, $1 > x > 0$
  - unmatched $\Rightarrow 0$

A simple example

Timing (no Signaling)

1. Preferences are realized.
2. Each firm makes **up to one** offer to one worker. Firms make offers simultaneously.
3. Each worker accepts up to one of the available offers.

Sequential equilibrium, anonymous strategies.

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Unique equilibrium: firm: offer to most preferred worker.
Expected outcomes:

- Matches: 1.5.
- Firm payoff: 0.75.
- Worker payoff: $(2+x)/4$.

A simple example

Timing (with Signaling)

1. Preferences are realized.
   - Each worker sends **up to one** signal to one firm. Workers send signals simultaneously.
   - Each firm observes their own signals only.
2. Each firm makes **up to one** offer to one worker. Firms make offers simultaneously.
3. Each worker accepts up to one of the available offers.

Sequential equilibrium, anonymous strategies

- Non-babbling equilibria where firms interpret a signal as a sign of interest.
- Half the cases: one firm gets two signals: same as no signals.

A Simple Example

Each firm receives exactly one Signal

If firm receives signal from top worker

- make an offer that will be accepted.

If firm receives signal from second choice worker:
Two pure strategies:

- **Ignore**: Firm makes offer to top choice worker, and ignores the signal
- **Respond**: Firm makes an offer to the second choice worker who sent a signal.

Equilibria in pure strategies

- **(respond, respond)** is always an equilibrium
  - if firm 2 is responding, firm 1 must respond!
- **(ignore, ignore)** is also an equilibrium if $x < 0.5$

firm 1\firm 2	**Respond**	**Ignore**
Respond	x	x
Ignore	0	$\frac{1}{2}$

Payoff of firm 1 with signal from 2^{nd} choice worker only

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Payoff of firm 1 with signal from 2^{nd} choice worker only

- a firm responding to signals: negative externality on payof of the other firm.
- strategies of firms are strategic complements.
  - If a firm responds to signals, then the other firm is weakly better off from responding to signals as well.

Observations from the simple example that generalize

	Firm Profits	Worker Profits	# Matches
Respond - Respond	$(5+2x)/8$	$3/4$	$7/4$
Ignore - Ignore	$3/4$	$(2+x)/4$	$3/2$

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- Firms: $(\textit{Ignore}, \textit{Ignore}) \succ_f (\textit{Respond, Respond})$
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- # of matches: (Respond, Respond) $>$ ($\textit{Ignore}$, $\textit{Ignore}$)

Model

Model

- F firms, W workers
- Ordinal preferences
  - $\theta_f \in \Theta_F$ – firm f's preference list (strict)
  - $\theta_w \in \Theta_W$ – worker w's preference list (strict)
  - θ_f and θ_w are i.i.d.
- Cardinal utility of agent a
  - $u_a(\cdot, \theta_a) > 0$, consistent with θ_a, $u_a(\varnothing, \theta_a) = 0$
  - for any permutation σ, $u_a(\sigma(\theta_f), \sigma(w)) = u_a(\theta_f, w)$

Timing

1. Preferences are realized.
2. Each firm makes **up to one** offer to one worker. Firms make offers simultaneously.
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Sequential equilibrium, anonymous strategies.

Workers accept the best available offer in the last stage.
Whom should a firm make an offer?

The Offer Game with no Signals

Proposition 1: Offer Game with No Signals
Unique equilibrium when firms use anonymous strategies and workers accept the best available offer is:
Firm makes an offer to the first choice worker.

The Offer Game with Signals

Timing (with Signaling)

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Signaling Phase

What equilibria do exist?

- Workers send their signal to their first choice firm, firms interpret signals as sign of interest, increases the chance to receive an offer.

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- Workers send their signal to their first choice firm, firms interpret signals as sign of interest, increases the chance to receive an offer.
- Babbling equilibria: No information is transmitted.
- "Perverse" equilibria, where firms interpret signals negatively, and workers nevertheless send such signals do not exist.

Focus on non-babbling equilibria, where workers sends a signal only to her most preferred firm.

Firm Strategies

The firm will decide whether to make an offer to

- Top ranked worker
- Highest ranked worker among workers who sent that firm a signal (signal worker)

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Definition: Strategy σ_f is a *cutoff strategy* for firm f if $\exists j_1, \ldots, j_W \in [1, W]$: for any $\theta_f \in \Theta_f$ and any set of workers $\mathcal{W}^S \subset \mathcal{W}$ who sent a signal we have,

$$\sigma_f(\theta_f, \mathcal{W}^S) = \begin{cases} S_f(\theta_f) & \text{if rank } \theta_f(S_f) \leq j_{|\mathcal{W}^S|} \\ T_f(\theta_f) & \text{otherwise.} \end{cases}$$

We call $(j_1, ..., j_W)$ f 's cutoff vector.

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Cutoff strategies are optimal: Other firms use anonymous strategies and workers signal to their most preferred firms:

- for any strategy of firm f there exists a cutoff strategy with a weakly higher expected payoff

Proposition 2 (Strategic Complements).
Suppose workers send signals to their most preferred firms and accept their best available offer, and suppose all firms use cutoff strategies and firm f uses a cutoff strategy that is a best response. If one of the other firms responds more to signals, then the best response for firm f is to also weakly respond more to signals.

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Intuition:

- When other firms make offers to worker that signaled to that firm: Becomes risky to make an offer to a worker who has not sent a signal.
- Such a worker signaled to another firm, that is now more inclined to make that worker an offer.
- The greater this inclination (the more firms respond to signals), the riskier for the firm to make an offer to its most preferred overall worker.

Theorem 1 (Equilibrium Existence).
In the offer game with signals, there exists a symmetric equilibrium in pure cutoff strategies where

1. workers signal to their most preferred firms and accept their best available offer
2. firms use symmetric cutoff strategies.

Furthermore, there exist pure symmetric equilibria with smallest and largest cutoffs.

Strategic complements allows us to use Milgrom and Roberts (1990) Theorem 5.

Theorem 2 (Welfare).
Consider any non-babbling symmetric equilibrium of the offer game with signals in which for at least some number of signals, firm strategies call for an offer to the signaling worker, S_f, even when she is not the first choice worker T_f. Then the following three statements hold.

1. The expected number of matches is strictly greater than in the unique equilibrium of the offer game with no signals.
2. The expected welfare of workers is strictly greater than in the unique equilibrium of the offer game with no signals.
3. The welfare of firms may be greater or smaller than in the unique equilibrium of the offer game with no signals.

Intuition:
1.A worker that sent a signal is more likely to accept than any other worker.
2. Follows from 1. and symmetry.
3. A firm responding to signals provides negative externalities to other firms (who are less likley to have the offer to their top choice worker who hasn't sent a signal being accepted).

Correlated Preferences

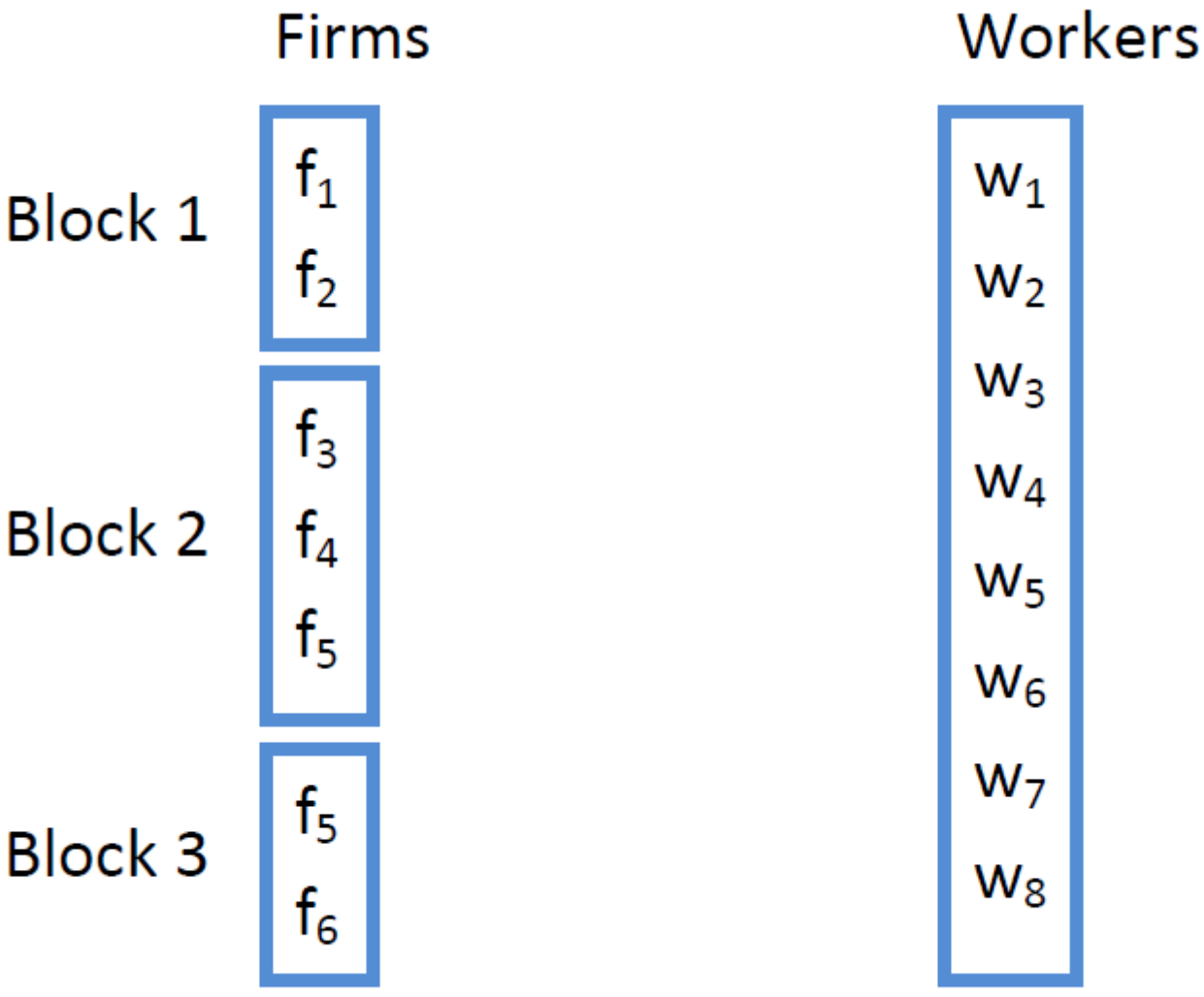
What if worker preferences are correlated?

Sending a signal to the first choice worker will not necessarily be optimal anymore?

How should firms respond to signals?

Model: Block correlated preferences: Workers agree on broad ranking of firms, but not on exact ranking within a block.

Block-correlated preferences



Block-symmetric sequential equilibria

Definition: *Block-symmetric sequential equilibrium*:

- Firms that are within each block use the same anonymous strategy and have the same beliefs.
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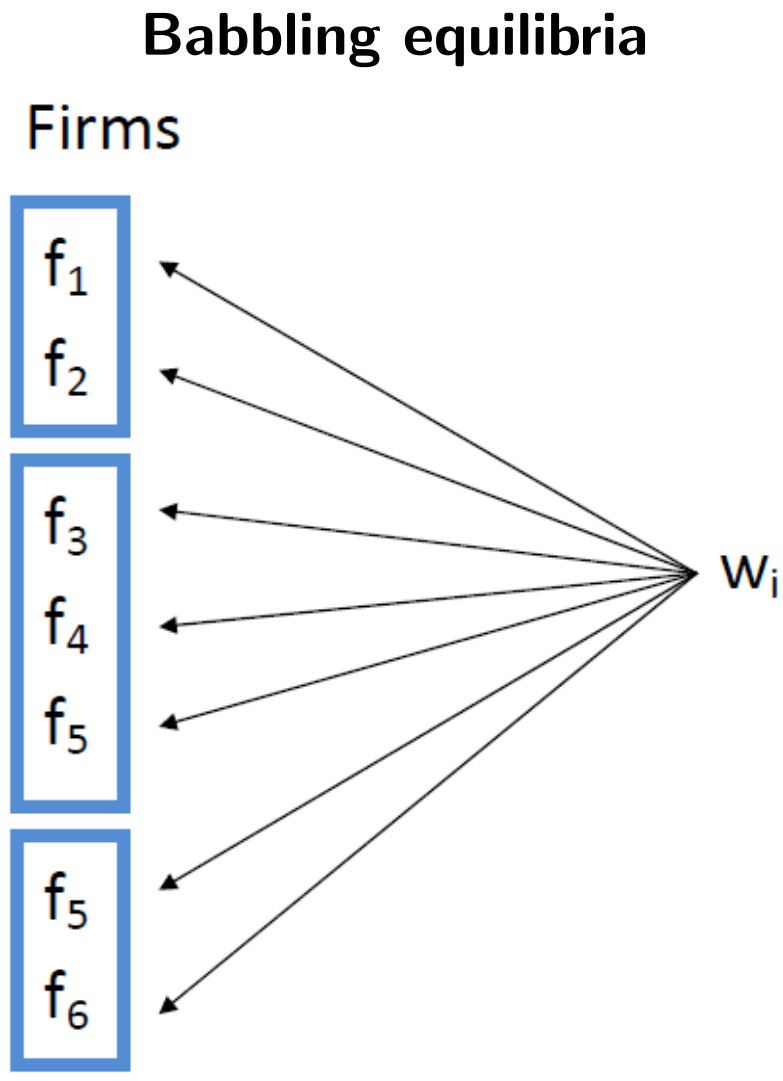
Characterization

Let us consider some block-symmetric sequential equilibrium that satisfies criterion D1. Then either

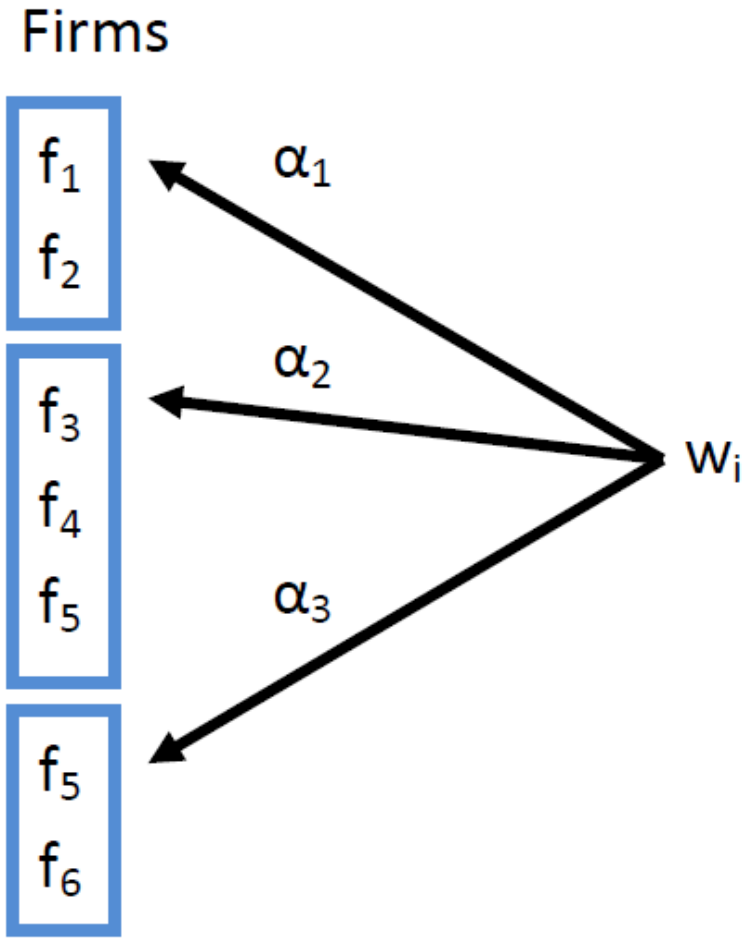
1. The equilibrium is a babbling equilibrium or
2. Workers use top-block strategies and firms have top-block beliefs

Block-symmetric sequential equilibria



Block-symmetric sequential equilibria

Top-block equilibria



- $0 \leq \alpha_i \leq 1$
- $\sum \alpha_i \leq 1$

Theorem 3 (Equilibrium Existence under Block Correlation). There exists a block-symmetric equilibrium where

1. workers play symmetric best-in-block strategies,
2. firms play blocksymmetric cutoff strategies.

Theorem 4 (Welfare under Block Correlation).
Consider any non-babbling symmetric equilibrium of the offer game with signals, in which there is a block with at least two firms such that workers send them signals with strictly positive probability. Then,

1. The expected number of matches is strictly greater than in the unique equilibrium of the offer game with no signals.
2. The expected welfare of workers is strictly greater than in the unique equilibrium of the offer game with no signals.
3. The welfare of firms may be greater or smaller than in the unique equilibrium of the offer game with no signals.

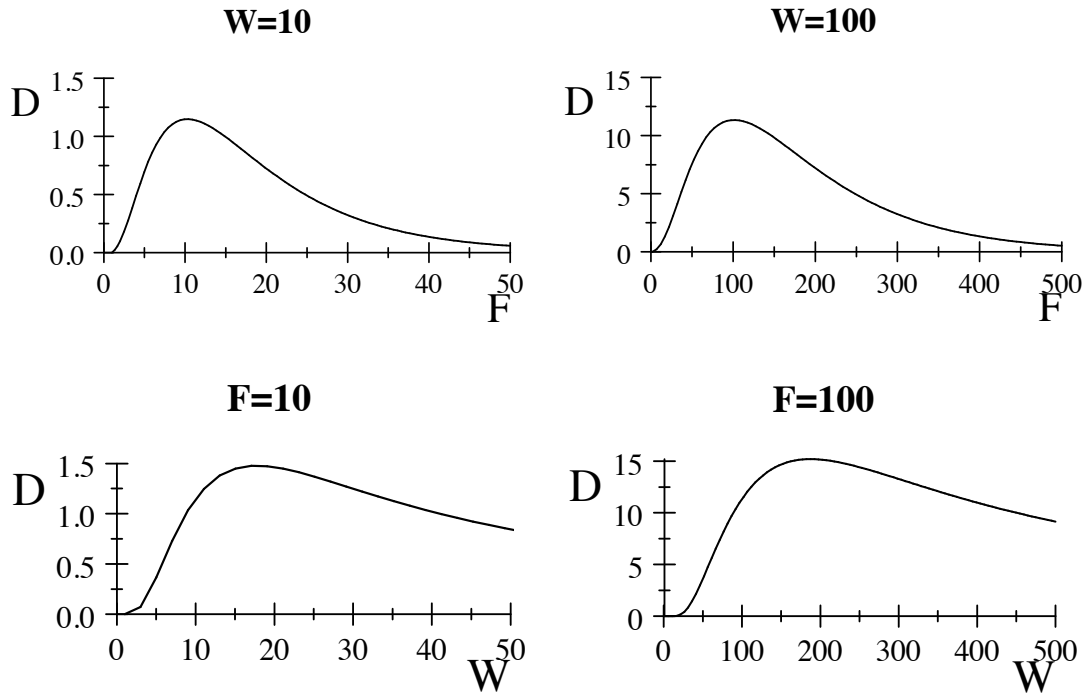
Market structure and the value of a signaling mechanism

Pure coordination model

- One block of firms, $B = 1$
- Firms care only about obtaining a match
  - for any $w \in W$, $f \in F$, $u_w(f, \theta_w) = u_w > 0$

The value of a signaling mechanism

$D(F, W)$ - the expected increase in the number of matches from the introduction of the signaling mechanism



The value of a signaling mechanism for large markets

Proposition: $D(F, W)$ is "almost" a homogeneous of degree one

- $D(F, W) = F\alpha(\frac{W}{F}) + O_F(1)$
- $D(F, W) = W\beta(\frac{F}{W}) + O_W(1)$

where $O_F(1)$ and $O_W(1)$ are functions that are smaller than a constant for large F and W correspondingly.

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Proposition:

- For fixed W, $D(F, W)$ attains its maximum value at $F \simeq 1.0121W + O_W(1)$.
- For fixed F, $D(F, W)$ attains its maximum value at $W \simeq 1.8842F + O_F(1)$.

Conclusion:

Market Design as a Noun:
Present a model to account for markets with the three stylized features:

1. Substantial frictions lead to market congestion:
   - employers cannot give full attention to all possible candidates
2. Applicants are ready to signal preferences over employers.
   - The markets found ways to make signals credible
3. Employers value this preference information and are prepared to act on it.

Market Design as a Verb

Present a simple way to help markets in congestion:

Introducing a signaling mechanism: Non-intrusive, cheap

Introducing Signaling in the Economics Job Market.

Is there congestion in the economics job market?

Some anecdotes:

- School 1: One open position, secretary accidentally copies all 700 applicants to confirm receipt of applications.
- School 2: Too many applications, only half are read.

Schools interview no more than 30 applicants per position.

How should schools select whom to interview?

- Top schools: Interview the most preferred candidates
- Other schools: May respond to congestion
  - Most preferred candidates may be unlikley to accept an offer (Truncation at the Top)
  - A number of candidates may be similar, and the department has to decide which one of those to interview (Randomization among candidates).

Irony: The cheaper and easier it is to submit an application: the harder it may be to find the "right" candidates.

- Market design question: Should we have a central letter/application website?
- Should Europe want to join the U.S. website?

AEA Job Market Committee

The Committee: John Cawley, Peter Coles, Phil Levine, Muriel Niederle, Al Roth, John Siegfied

Activities of the Committee:

- Scramble
- Platform for Postings / Applications
- Signaling

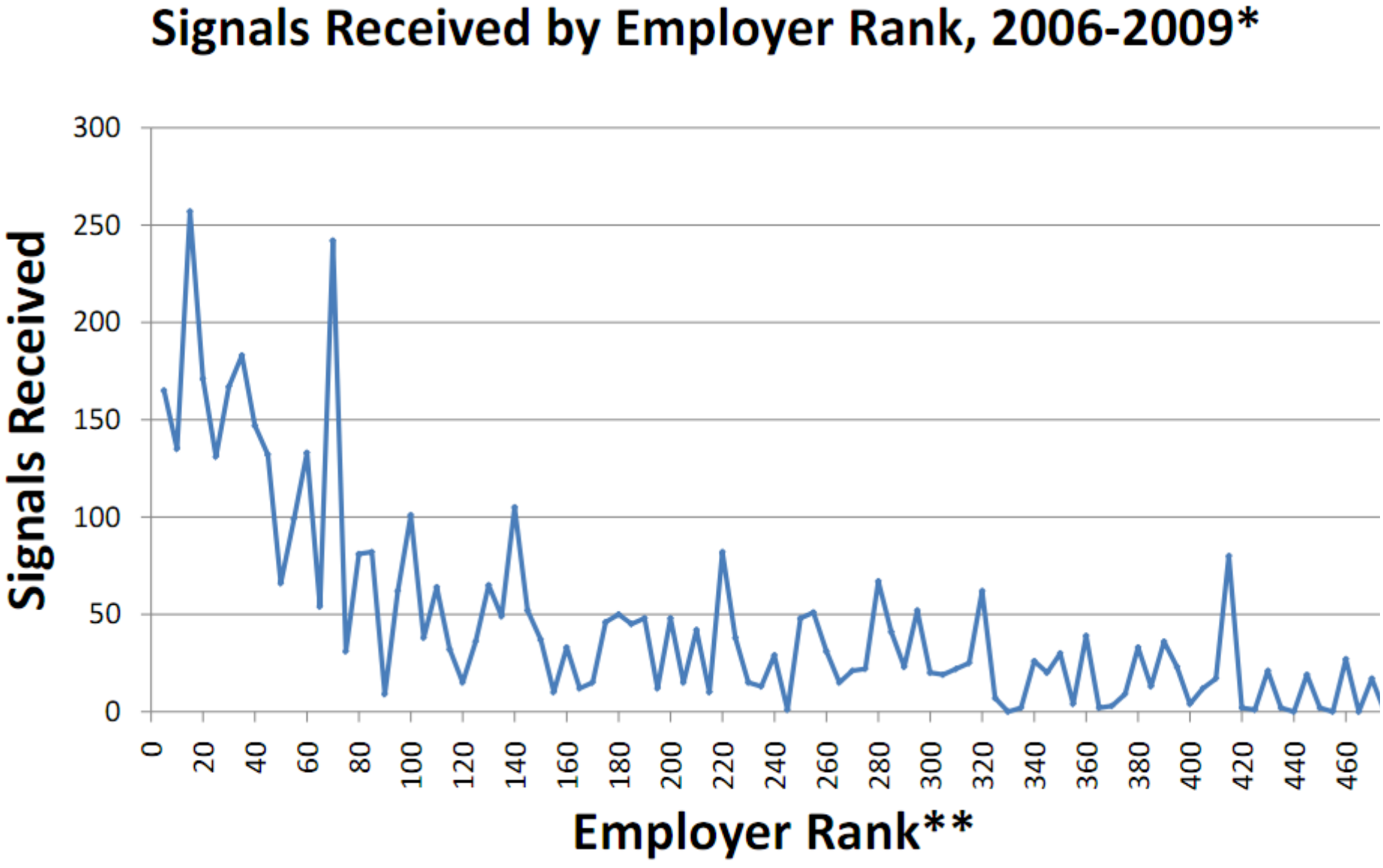
AEA Signaling

Advice from the AEA website:
http://www.aeaweb.org/joe/signal/signaling.pdf
"The two signals should not be thought of as indicating your top two choices. Instead, you should think about which two departments that you are interested in would be likely to interview you if they receive your signal, but not otherwise (see advice to departments, above). You might therefore want to send a signal to a department that you like but that might otherwise doubt whether they are likely to be able to hire you. Or, you might want to send a signal to a department that you think might be getting many applications from candidates similar to you, and a signal of your particular interest would help them to break ties. You might send your signals to departments to whom you don't have other good ways of signaling your interest"

Who signaled?

Year	# Signalers	#Signals	# Employers Signaled	# JOE Ads Signaled	# JOE Ads (entire year)	Fraction of JOE Ads Signaled
2006	971	1890	519	674	2643	25.5%
2007	1022	2010	489	672	2914	23.1%
2008	979	1926	461	687	2881	23.8%
2009	978	1922	449	666	2285	29.1%

Participation rate: 66 %


Signals Received by Employer Rank, 2006-2009*
Signals Received
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
Employer Rank**

Signal Flow (2006-2009)*,**

From↓ To→	Tier 1	Tier 2	Tier 3	Tier 4	UNRANKED	TOTAL
Tier 1	101	368	274	105	159	1007
Tier 2	111	478	521	385	646	2141
Tier 3	40	165	339	385	706	1635
Tier 4	15	84	116	179	603	997
UNRANKED	13	51	54	62	232	412
TOTAL	280	1146	1304	1116	2346	6192

* Tiers 1-4 are depts. ranked 1-10, 11-50, 51-150, and 151-480 respectively

** Includes signals to economics departments only

Is Signaling Effective?

- Problem: We do not know all applications sent by applicants.

Survey:

- Given an application to an employer:
  - Chance to get an interview: 15%
  - Application with Signal: 29%
- Problem: Selection in whom to send a signal.
  - Solution: ask about hypothetical third signal
  - Another option: Ask non-signalers.

Hypotheses

- Signaling is effective when sent to certain employers:
  - Liberal arts schools
  - International
  - Rural, Unranked...
- Signal is effective when chosen wisely

2009 AEA Signaling Survey Results

SIGNALS (1st and 2nd Choice)		**Interview**	**Flyout**	**Offer**	**Acceptance**
n = 567	y	162 (28.6%)	72 (12.7%)	38 (6.7%)	22 (3.9%)
	n	405 (71.4%)	495 (87.3%)	529 (93.3%)	545 (96.1%)

HYPOTHETICAL SIGNALS (3rd Choice)		**Interview**	**Flyout**	**Offer**	**Acceptance**
n = 162	y	38 (23.5%)	12 (7.4%)	6 (3.7%)	3 (1.9%)
	n	124 (76.5%)	150 (92.6%)	156 (96.3%)	159 (98.1%)

2009 Liberal Arts Breakdown:

ACTUAL SIGNALS		Interview	Flyout	Offer	Accept
n = 103	y	42 (40.8%)	13 (12.6%)	6 (5.8%)	3 (2.9%)
	n	61 (59.2%)	90 (87.4%)	97 (94.2%)	100 (97.1%)
HYPOTHETICAL SIGNALS		**Interview**	**Flyout**	**Offer**	**Accept**
n = 37	y	7 (18.9%)	2 (5.4%)	2 (5.4%)	1 (2.7%)
	n	30 (81.1%)	25 (94.6%)	35 (94.6%)	36 (97.3%)

SIGNALS (NON-LIB ARTS, ACADEMIC)		Interview	Flyout	Offer	Accept
n = 400	y	102 (25.5%)	51 (12.8%)	29 (7.3%)	16 (4.0%)
	n	298 (74.5%)	349 (87.3%)	371 (92.8%)	384 (96.0%)
HYPOTHETICAL SIGNALS (NON-LIB ARTS, ACADEMIC)		**Interview**	**Flyout**	**Offer**	**Accept**
n = 113	y	26 (23.0%)	8 (7.1%)	3 (2.7%)	1 (0.9%)
	n	87 (77.0%)	105 (92.9%)	110 (97.3%)	112 (99.1%)

Where are Signals valuable?

Suggestive evidence for

- Liberal arts colleges
- Departments in towns Pop $<$ 50,000
- "unranked" schools
- non-current Ph.D's
- Departments that don't receive many signals.

Signaling

- More and more departments list in the JOE ad that they would look at sognals
- Hard to assess the impact on efficiency in the field
- Survey results suggest that departments value signals.