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Social Networks:
Applications to Labor Markets

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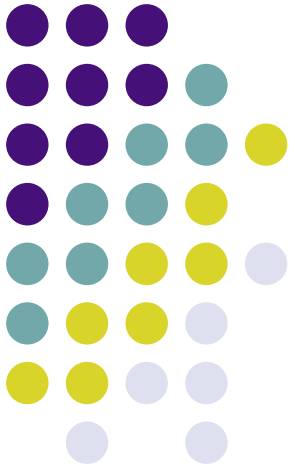
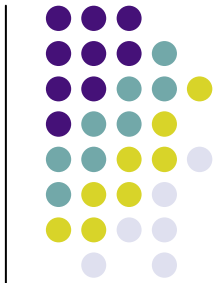
Social Networks: Applications to Labor Markets

Matthew O. Jackson

Trieste Summer School on Networks



Markets and Networks

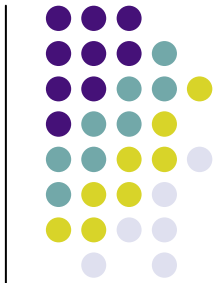


- Traditional Models of Markets:
  - Centralized
  - Search Models
- Networks of Contacts are Important in Many Markets
  - Currency Markets
  - B to B, Supply chains,
  - Labor Markets
  - ...

Broader Research Agenda:

- How do networks impact interactions?
  - E.g., how are networked interactions different from others?
- What are the incentives to form networks?
  - Do Pareto efficient networks form on their own?
  - How to help if they do not?

Outline of Lecture



- Background on Networks in Labor Markets
- Stylized Facts of Labor Markets
- Network Models, Examples and Results
- Concluding Remarks

Networks in Labor Markets

- Myers and Shultz (1951)- textile workers:
  - 62% first job from contact
  - 23% by direct application
  - 15% by agency, ads, etc.
- Rees and Shultz (1970) – Chicago market:
  - Typist 37.3%
  - Accountant 23.5%
  - Material handler 73.8%
  - Janitor 65.5%
  - Electrician 57.4%…

More on Contact Networks

- Granovetter (1974) study across job type
  - 44% of technical jobs by contact
  - 56% of professional jobs by contact
  - 65% of managerial jobs by contact
- Corcoran et al. (1980) PSID – jobs by contact
  - White Males 52%
  - White Females 47.1%
  - Black Males 58.5%
  - Black Females 43%

Use of Social Contacts Across Countries:

- Pellizzari (2004):
  - no systematic differences in use of contacts across European countries and US
  - more prevalent in private sector
  - more prevalent with lower education and skill
  - more prevalent in smaller, medium sized firms
  - apparent differences in wage premium/penalty to use of social contact across countries, but with much variation within EU (US at 0)

Features of Labor Markets We Can Help Explain with Network Models

- Correlation in employment across geography, acquaintances, profession (after correction for economy)
- Serial correlation patterns in individual employment – Duration Dependence
- Gap in wages between white and black males (after correction for skills, age, education...)
- Higher dropout rate for black versus white males

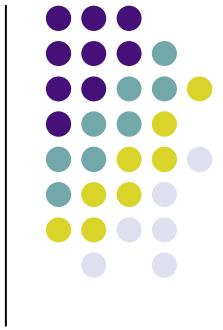
Let's look at these in some detail:

Inequality in Wages and Drop-Out Rates

- Card and Krueger (1992), Chandra (2000)…
  - Black-White wage gap is about 25 to 40%; only partly explained by differences in skill levels, quality of education

- Heckman, Lyons, and Todd (2000), Card and Krueger (1992), Chandra (2000)…
  - Dropout rates 2.5 to 3 time higher for blacks versus whites

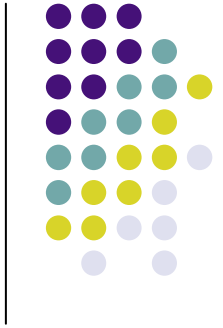
Inequality in wages



- Smith and Welch (1989) U.S. Census Data
  Black to white wage ratios by education level

Education:	1940	1950	1960	1970	1980
0-7 years	54.5%	63.6%	67.0%	73.9%	82.5%
8-11 years	59.7%	70.9%	70.1%	78.8%	74.8%
12+ years	56.5%	66.5%	66.2%	72.2%	78.8%

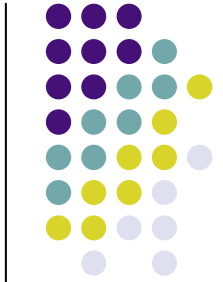
Drop-Out Rates



- Chandra (2000) Census – males 25 to 55

	1940	1950	1960	1970	1980	1990
whites	3.3	4.2	3.0	3.5	4.8	4.9
blacks	4.2	7.5	6.9	8.9	12.7	12.7

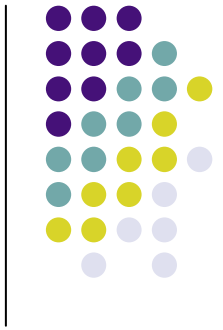
Duration Dependence



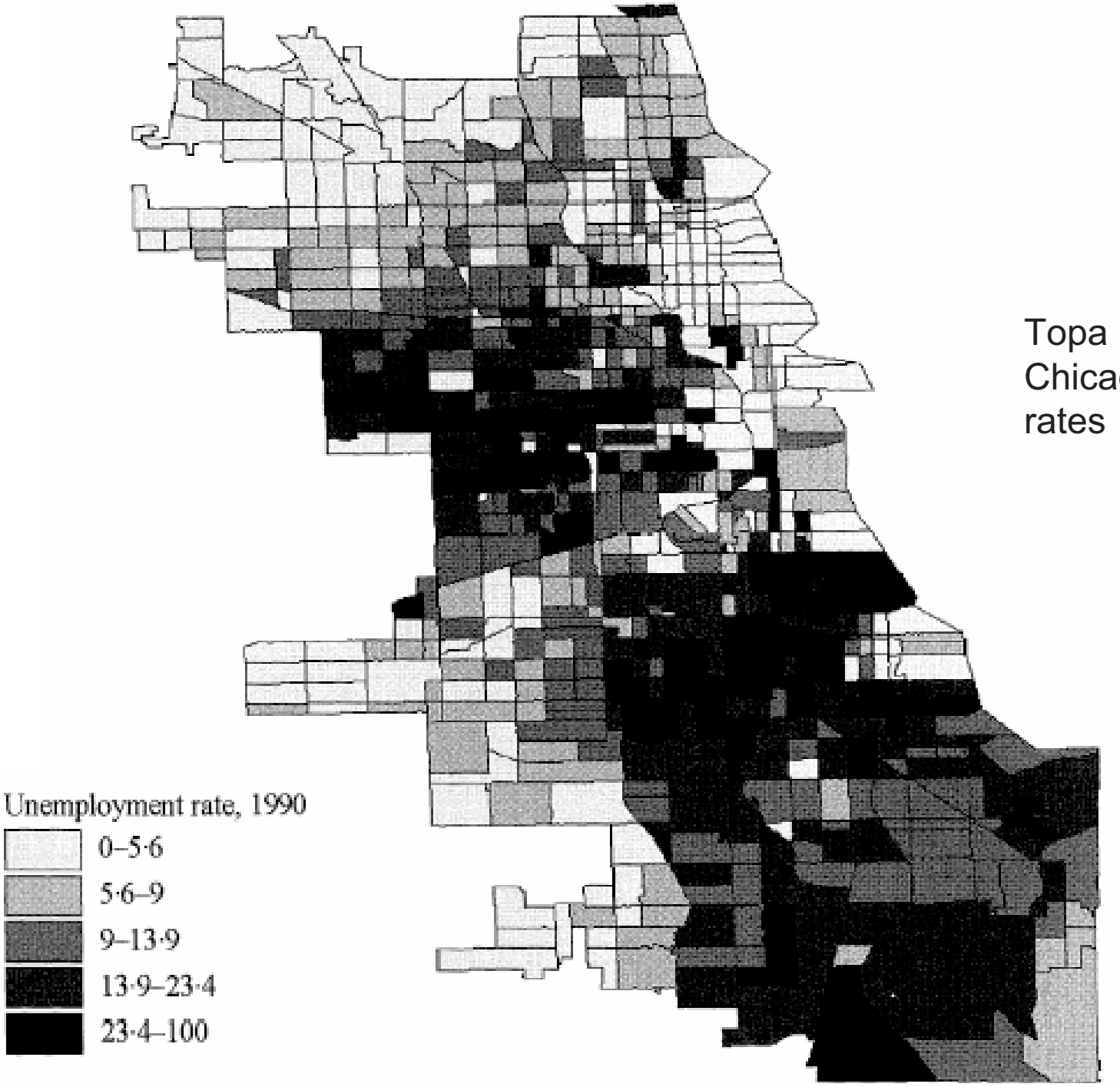
- Lynch (1989) Probability finding a job in the next week, given number of weeks unemployed:

Weeks unemployed:	1	8	52
Probability Finding Job:	.30	.08	.02

Correlation Patterns:



- Topa (2001)
  - Geographic Correlation in Unemployment (correcting for economic conditions) - proximity to other employed agents helps explain employment
  - Strong Social Interaction within areas
- Conley and Topa (2001)
  - Correlation in proximity of travel time, occupation, ethnicity – with ethnicity and race dominant factors

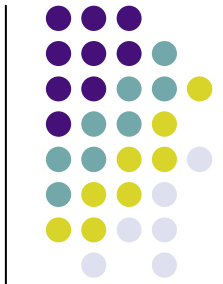


Topa (2001)
Chicago Unemployment rates 1990

Models and Hypotheses regarding Networks in Labor Markets

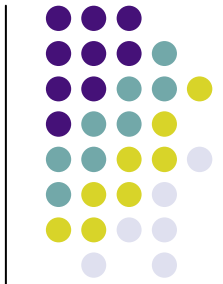
- Granovetter (1973, 1995), Boorman (1975), Montgomery (1991, 1992, 1994), …
  - Weak versus Strong ties – who to connect to
- Arrow and Borzekowski (2001)
  - Difference in number of offers affects wages
- Calvo-Armengol and Jackson (2004ab)
  - job offers through network, model employment, wages and dropout decisions

Arrow-Borzekowski: Second Price Auction



- Number of opportunities is proportional to degree
- value of match for each opportunity is iid Uniform on [0,v]
- expected wage if degree is k is (ak-1)v/(ak+1)
  - increasing in degree
  - concave in degree
- value of match increasing and concave in degree: akv/(ak+1)

Relating Network Structure to Outcomes

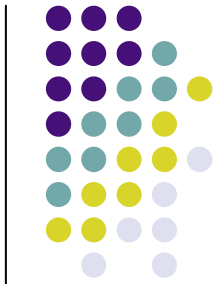


(Jackson-Rogers 2005) Degree Distributions of Regular networks SOSD E-R networks SOSD scale-free networks of same average degree.

Therefore: if wage and match value are concave in degree (as in the Arrow and Borzekowski model), then average wages and social value are ranked as follows (holding average degree fixed):

Regular>E-R>Scale-Free

Aside: second order stochastic domination



P and P' are distribution functions

Theorem (Rothschild and Stiglitz (1970)):

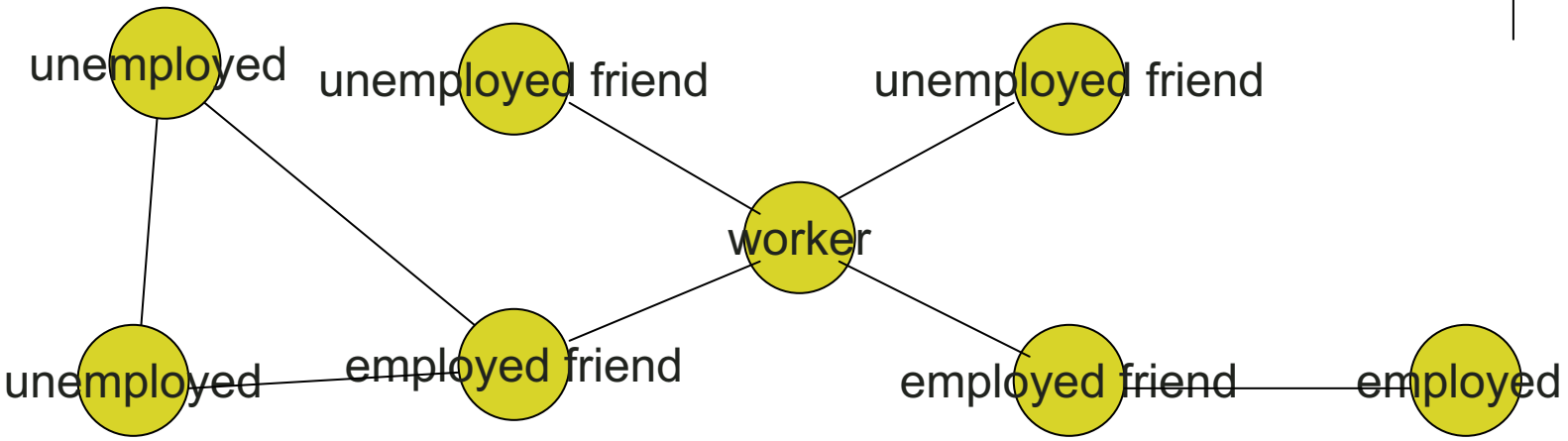
The following are equivalent

- P SOSD P'
- $\int f\,dP > \int f\,dP'$ for all increasing, concave f
- $\int_0^x [P'(k)-P(k)]dk > 0$ for all x

If P and P' have the same mean then the above are also equivalent to

- P' is a mean-preserving spread of P
- $\int f\,dP > \int f\,dP'$ for all concave f

Model of Labor Networks (Calvo-Jackson (2004ab))

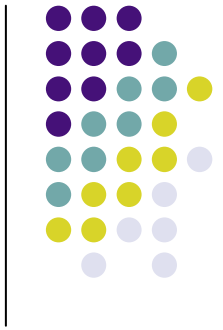


- network describes who knows whom, intensities
- workers hear about jobs (random arrival process)
- decide whether to keep information or pass it on to a friend/relative/acquaintance - might pass repeatedly and/or to many agents
- workers lose jobs (random breakup process)
- friends of a friend help and hurt

Model Details

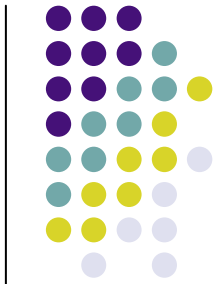
- N={1,…,n} agents
- t in {1,2,…} periods
  - Two parts:
    - Hiring phase: hear about jobs and pass information
    - Breakup phase: randomly lose jobs
- Variables to keep track of
  - S_{it} the end of period employment of worker i
  - W_{it} the end of period wage of worker i

A Simple Example – Homogeneous Jobs



- Network (n by n {0,1} matrix g) describes who knows whom
- All jobs are identical and pay same wage
- Jobs arrive to an agent with probability a
- Lose jobs with probability b
- If employed, then randomly pick an unemployed friend to pass the job to

Get a Markov Process

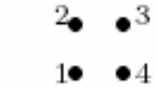
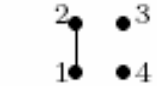
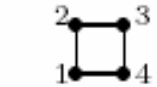
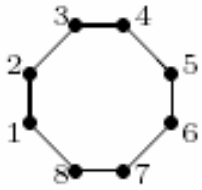
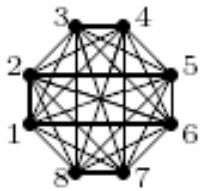


- State is list of employment/wage status of each agent
- More likely to hear about jobs when friends are (well) employed
- More likely to pass on information when have a (good) job

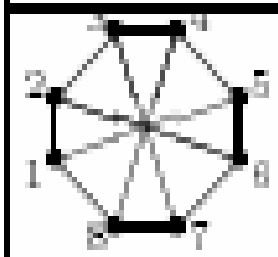
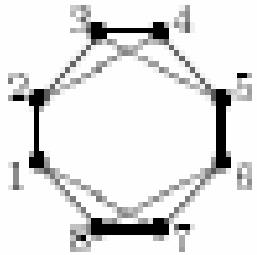
Transition Probabilities

- $p_{ki}(w)$ - probability that k passes a job to i
- $p_i(w)$ – expected number of jobs i hears about given current state w
  - $p_i(w)$ is nondecreasing in w_{-i} and nonincreasing in w_i
  - $p_i(w)$ is positive if i is not at highest wage level
- Wage is nondecreasing in number of offers and starting wage (e.g., from Arrow-B)
- Lose job with probability b_i

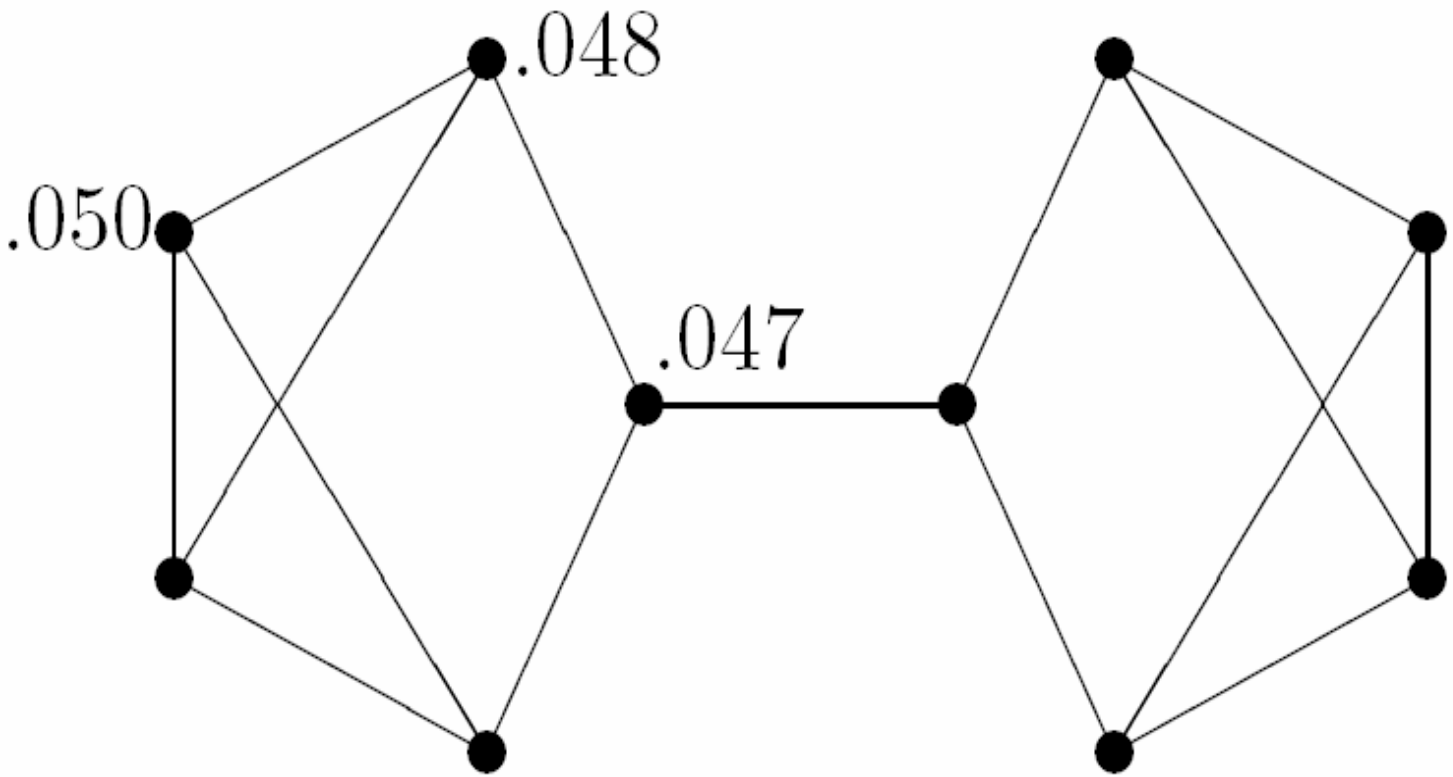
Homogeneous Example with a=.100 and b=.015

	Prob Unemployed	Corr 1 and 2	Corr 1 and 3	Corr 1 and 4
	.132	–	–	–
	.083	.041	–	–
	.063	.025	.019	–
	.050	.025	.025	–
	.060	.023	.003	.001
	.030	.014	.014	.014

Structure Matters

g	average path length	average unemployment
	1.571	.048
	1.786	.049

Position Matters

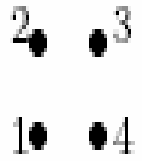
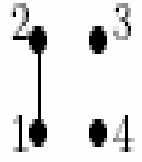
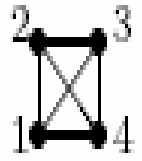


Result on wage correlation:

Consider an economy (N,p,b). The wages and employment of any path-connected agents are positively correlated (in fact, strongly-associated) under the unique steady state distribution. The same is true across any times starting from the steady state distribution.

- Proof challenge: Do friends of a friend help or hurt?
  - Compete with me for information about jobs
  - But help keep my friends well-employed

Duration Dependence: Prob of Getting Job Conditional on Length of Unemployment

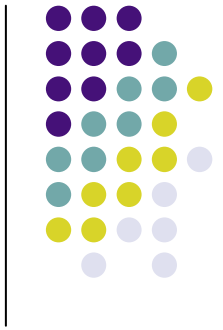
Network	1 period	2 periods	10 periods	limit
	.099	.099	.099	.099
	.176	.175	.170	.099
	.305	.300	.278	.099

Result on duration dependence

Consider an economy (N,p,b) such that p is a function of employment. Agents' employment exhibits duration dependence; that is,

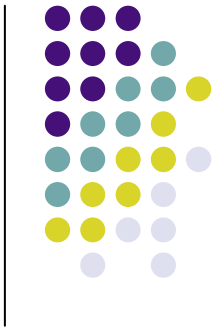
$$\text{Prob}(S_{i,t}=1 \mid S_{i0}=0, \ldots, S_{it-1}=0)$$
$$< \text{Prob}(S_{i,t}=1 \mid S_{it'}=0, \ldots, S_{it-1}=0)$$

Remarks on the Patterns and Dynamics



- Correlation gives the observed clustering and correlation patterns
- Duration dependence comes out due to the inferred state of the network
- There will be natural cycles in this setting:
  - Cyclic unemployment even if arrival/breakup are stationary
  - More employed leads to higher probability stick there, and similarly for less employed

Relate Employment to Network Structure:



(Jackson and Lopez-Pintado):

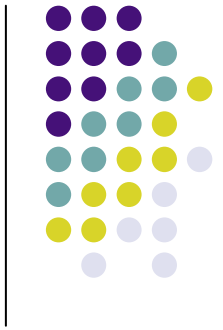
In the homogeneous job setting, if P(k) SOSD P'(k) then average employment is higher under P than under P', as is the employment rate for nodes of any fixed degree.

- Recall, keeping average degree fixed:

Regular network SOSD Exp SOSD Scale-free.

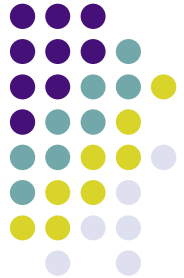
[no critical a/b, unless only employed hear, then need a/b>1 regardless of degree distribution]

Dropping Out



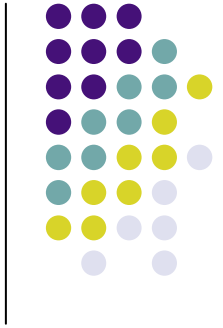
- Cost to getting education, maintaining skills, looking for employment, etc.
- Dropout if outlook for employment is poor
- Outlook is poor if bad starting conditions
- Outlook is poor if network connections are not diverse
- Contagion: Dropout if many acquaintances dropout

Model as a game



- Agents decide whether or not to drop out
- Compare discounted value of expected future wages to cost of staying in.
- This game is supermodular – if more agents stay in, then i's payoff from staying in is higher
- There exists a ``maximal'' equilibrium – we focus on that, (but could equally well compare minimal equilibria)

Player's decision:

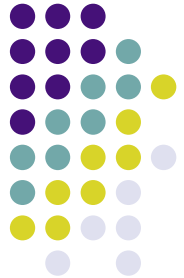


Number of Contacts In

	0	1	2	... n
Stay In	$E[w\|0,s]-c_i$	$E[w\|1,s]-c_i$	$E[w\|2,s]-c_i$	$E[w\|n,s]-c_i$
Drop Out	0	0	0	0

Dropout Example

c_i U[.8,1], discount .9, w=1, a=.1, b=.015



All Start Employed	$n = 1$	$n = 2$	$n = 4$	$n = 16$	$n \to \infty$
Dropout Percentage	58.3	44.5	26.2	9.7	6.8
Percentage Due to Contagion	0	8.8	5.0	0.4	0

All Start Unemployed	$n = 1$	$n = 2$	$n = 4$	$n = 16$	$n \to \infty$
Dropout Percentage	100	97.8	92.9	68.0	56.8
Percentage Due to Contagion	0	12.1	21.7	8.7	0

Result on dropouts:

Consider an economy (N,p,b,c,d). Consider two different starting states w and w' with w' ≥ w.

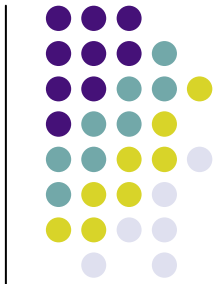
(i) The maximal equilibrium dropouts following w' are a subset of those under w, with strict inclusion for some costs and discount rates.

(ii) For agents who stay in, expected wages starting from w' strictly first order stochastically dominate those starting from w, at all dates.

Application to Social Mobility

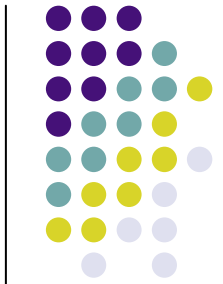
- Correlation in parent-child log(earnings) [Solon (1992), Zimmerman:
  - in [.4,.6] US and UK
  - in [.2,.4] in Germany, Sweden
- Higher numbers if look at income
- Numbers for father-son, higher for daughters

Application to Social Mobility



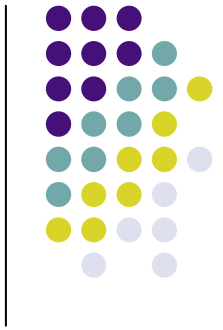
- Parent child log earnings correlations:
  - [.4,.6] in the US [Solon (1992), Zimmerman (1992),Mulligan (1997)...]
  - [.1,.4] Canada, Finland, Germany, Sweden [Corak and Heisz (1999) ; Osterbacka (2001); Couch and Dunn (1997), Wiegrand (1997); Bjorklund and Jantti (1997), Gustafsson (1994), Osterberg (2000)...]
  - [.4,.6] U.K. [Atkinson, Maynard, and Trinder (1983), Dearden, Machin, Reed (1997)]
  - .45 South Africa [Hertz (2001)]
  - ....

Income and Class Mobility



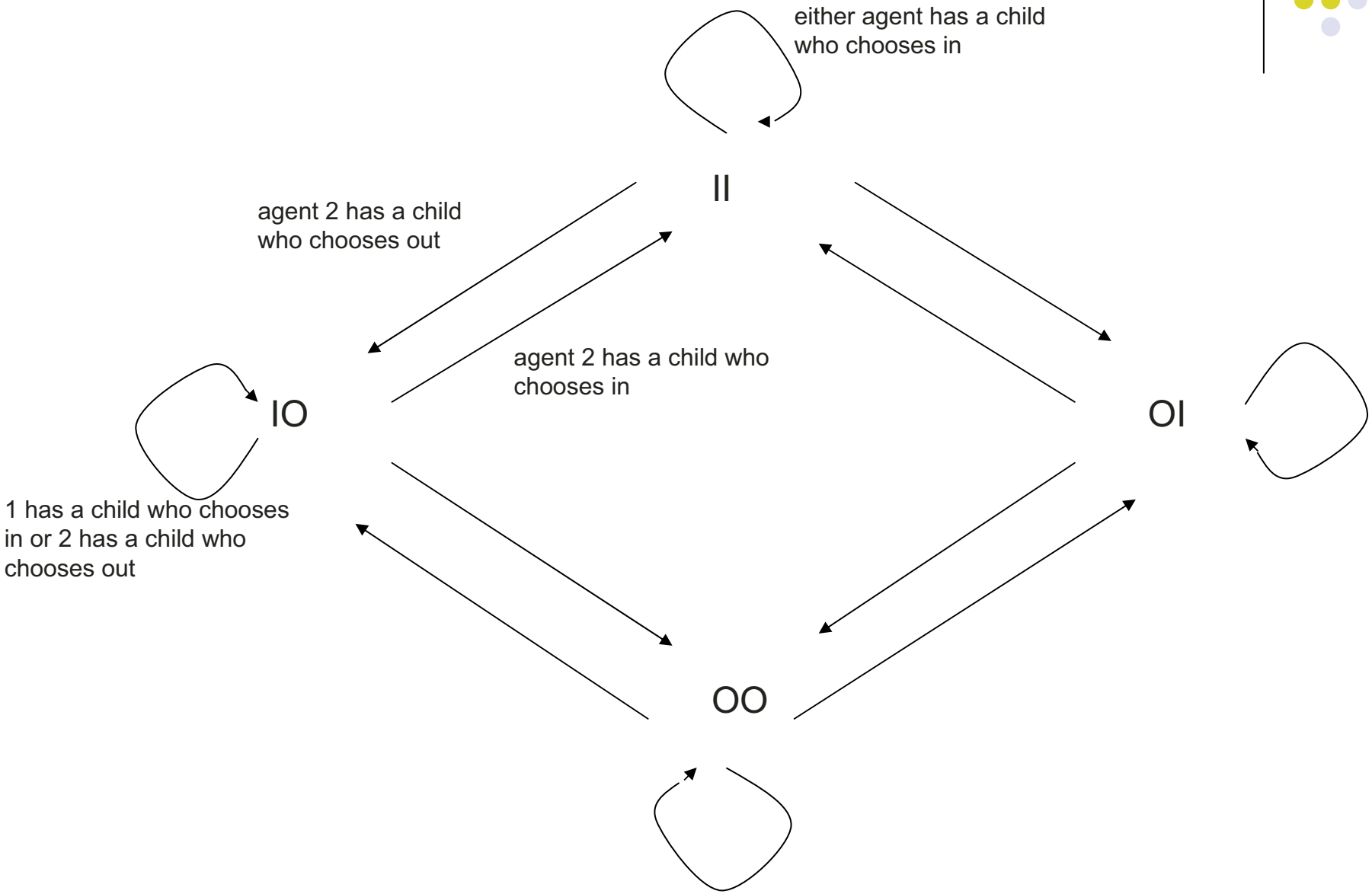
- Income correlations are higher: .7 and above
  - Higher when include daughters [Mulligan (1997)]
  - Non-linear in income levels - higher in the tails [Cooper, Durlauf, Johnson (1994)]
- Odds Ratios [prob(same class)/prob(change class)] are very high: ranging from 1 to 15 depending on class, etc.
  - Hout (1983), Erikson and Goldthorpe (1992), Breen (1994), Ishida (1995)...

Drop Outs over time

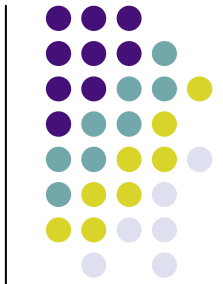


- Drop out decisions over time
- Parent replaced by child
- Randomly pick node to replace
- Correlation comes from similarity of network

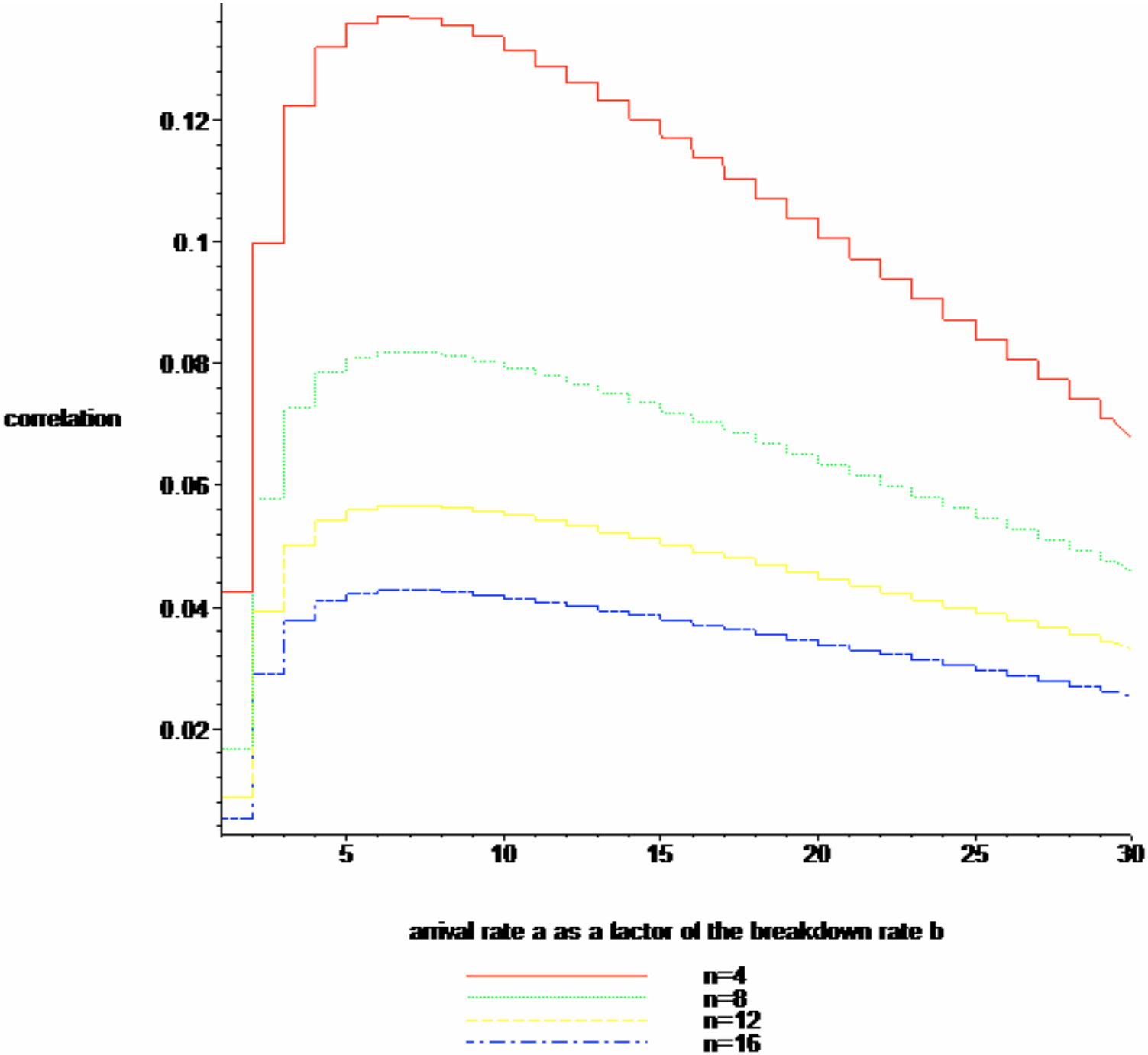
Correlations
A Dyad Example:



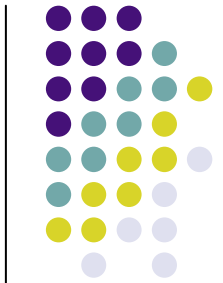
Dyad probabilities:



- II occurs with prob $p_0\, p_1 /(1+ p_0 – p_1)$
  - increasing in both p_0 and p_1,
- IO,OI occurs with prob $p_0\, (1-p_1)/(1+ p_0 – p_1)$
  - increasing in p_0 and decreasing in p_1,
- OO occurs with prob $(1- p_0)(1-p_1)/(1+ p_0 – p_1)$
  - decreasing in both p_0 and p_1,


0.12
0.1
0.08
0.06
0.04
0.02
corelation
5
10
15
20
25
30
arrival rate a as a factor of the breakdown rate b
n=4
n=8
n=12
n=16

Conclusions

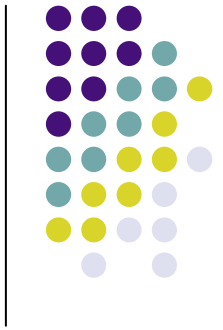


- Network effects help understand labor market patterns:
  - clustering and correlation
  - duration dependence
  - drop-out rates
  - persistent inequality in wages and employment
  - social mobility patterns
- Network structure matters: more regular networks have higher average employment, higher average utility
- Policy: Local Increasing Returns to Subsidies - subsidize group of neighbors all at once

Things to Think About

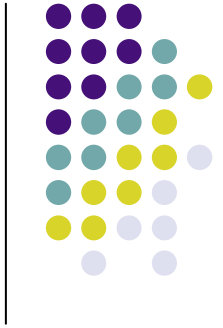
- Richer endogeneity of network
- Equilibrium model of wages and job arrival process
- Why are social contacts/networks used?

Role of Ethnicity/Race:



- Ethnic group status (as measured by average of father's cohort) plays a large role in economic status of child
  - Borjas (1992): correlation in status of father-child on order of .2+, and father's cohort-child on order of .2 to .5
- Wealth, race, education are more important than IQ in explaining heritability of earnings; parental status still important when education is well-measured
  - Bowles and Gintis (2002)

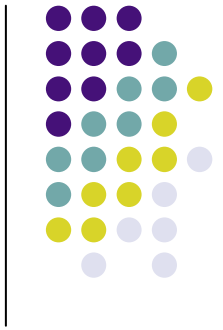
Wage Differentials:



- Holding education constant, class correlates with wages [Goux and Maurin (1997)...]

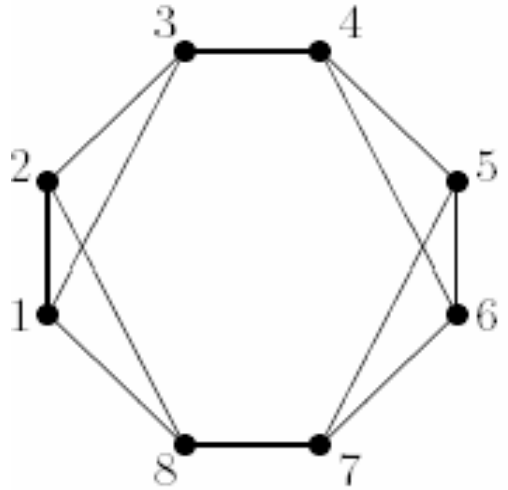
- College enrollment differential by race narrows in US [Kan (1994)], but black-white wage differential does not [Card and Krueger (1992), Chandra (1992) - on order of 25 to 40%...]

Previous Models of Social Mobility



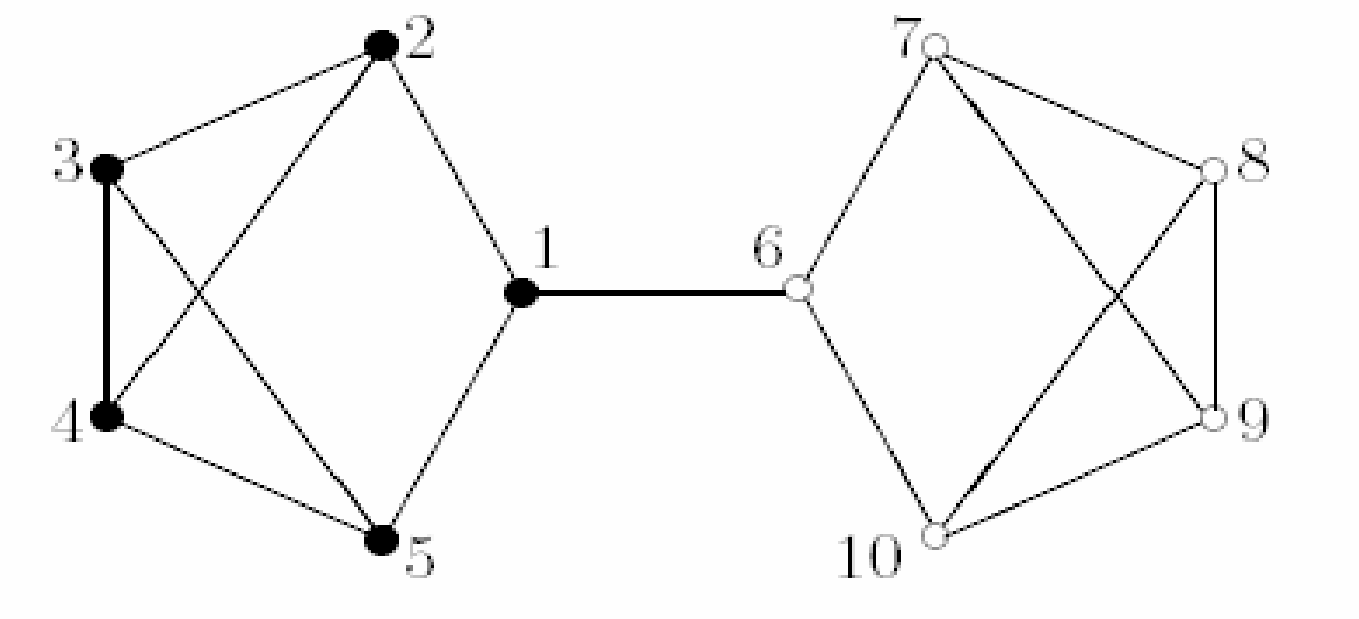
- Becker and Tomes (1979),
  - wealth transfers by altruistic parents
  - inheritance of abilities correlates human capital and earnings
- Loury (1981),
  - Imperfect credit markets - child's education decisions affected by parental wealth
- Benabou (1993, 1996), Durlauf (1996),
  - Education is a local public good – investment is lower in lower income areas – mobility tied to residential choice

Drop-out rates as a function of who is subsidized



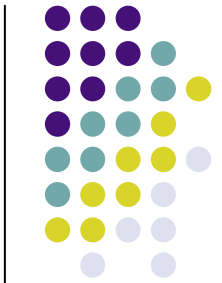
Agents Subsidized	Cost Range		
	.80 to 1	.84 to 1	.88 to 1
1 and 2	47.1	72.2	75.0
1 and 5	**42.1**	73.0	75.0
3 and 8	43.8	**70.9**	75.0

Dropouts in a connected Network



Agent	1	2	3	4	5	6	7	8	9	10
Drop-out Rate	.47	.42	.42	.42	.42	.91	.93	.93	.93	.93

Increasing Returns to Subsidies



- four individuals
- start in complete network
- cost actually decreasing if subsidize more - so this underestimates

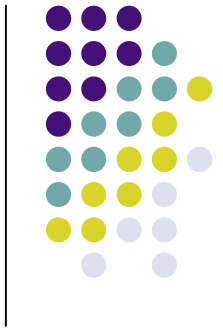
Number subsidized	Percentage Staying In
0	7.1
1	26.6
2	52.3

$$\underbrace{\frac{1}{2}\left[SI\left(2\right)+SI\left(0\right)\right]}_{29.7}>\underbrace{SI\left(1\right)}_{26.6}.$$

Dropout Rates - Comparative Statics

Costs [.8,1]		b					
		.015	.045	.075	.105	.135	.165
a	.05	69:27	100:0	100:0	100:0	100:0	100:0
	.10	27:5	99:27	100:0	100:0	100:0	100:0
	.15	17:2	76:27	99:12	100:0	100:0	100:0
	.20	13:1	52:13	97:28	100:0	100:0	100:0
	.25	11:1	42:10	83:26	100:16	100:0	100:0
	.30	10:1	37:9	68:18	98:24	100:2	100:0
	.35	9:1	29:3	61:15	88:24	100:12	100:0
	.40	9:1	27:2	53:11	84:23	96:20	100:0
	.45	7:0	25:2	46:7	76:18	91:20	100:6

Basic Elements of Calvo-Jackson Model



- Jobs obtained either directly hearing or from social contact hearing and passing information
- More and better placed social contacts lead to better information and prospects for jobs
- Friends of Friends help and hurt:
  - Help keep friends employed
  - But compete with me for job information

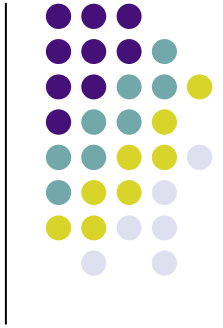
Results from a Network Model:

- Positive correlation across networked individuals, decaying with distance
- Future wage prospects depend on status of network – can get persistent gaps in wages based on starting conditions
- Drop-out decisions affected by network status – have contagion among dropouts
- Duration of employment depends on network status – get duration dependence

Other examples

- Agents are heterogeneous
  - they hear about jobs at different rates
  - they have different skills and qualifications
- Jobs are heterogeneous
  - keep good ones that improve current situation
- Pass information selectively
- Pass information to several agents
- Information is relayed through the network
- ...

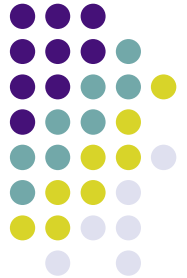
Theorem 2



Consider an economy (N,p,b). The wages of any path connected agents are positively correlated across any times starting from the steady state distribution.

Again, a similar result holds for employment.

Drop-outs at various turnover rates:



Scaled by factor of	1	3	5	7	9
a= b=	.05 .015	.15 .045	.25 .075	.35 .105	.45 .135
Dropout and contagion	69 27	76 27	83 26	88 24	96 20