Topics in Experimental and Behavioral Economics

Social behavior on networks

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Why of interest?

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1. Social embeddedness of economic decision making (Coleman AER 1984, Granovetter AJS 1985)
2. Strength of weak ties (Granovetter AJS 1973)
3. Networks structures and cooperation - Imitation and locality
4. Free choice for free people

Exogeneous & endogenous structures

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1. Cooperation on exogenously imposed structures
2. Cooperation on endogenosuly chosen structures

Social behavior on exogenous structures

Cassar 2002/2004

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- To which extent to network structures influence cooperation and coordination?
- Network structures can be:
  - **Local** → links form a simple lattice structure such as a circle or grid
  - **Random** → links are equally likely between each pair of agents
  - **Small-world** → local with a few links substituted by long-distance links

Game in network

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- Each agent is playing a 2×2 normal form game with all her neighbors
  Single strategy $\leftrightarrow$ no neigbor contingent choices
  Payoff to player i neighbor j

$\Pi = \sum_{j \in L_i} \pi_i(\sigma_i, \sigma_j)$	A_j	B_j
player i A_i	a, a	b, b
B_i	c, c	d, d

  L_i ... set of i's neighbors
  $l_i := |L_i|$ ... cardinality of L_i
- Coordination: $a > c$, $d > b$, $a > d$, $a - c < d - b$
  $(a = 5, b = -1, c = 4, d = 1)$
  $\Rightarrow$ all A payoff dominant, all B risk dominant
- Cooperation: $c > a$, $d > b$ and $a > d$ $(a = 4, b = 0, c = 5, d = 1)$
  $\Rightarrow$ all A Pareto efficient, all B standard Nash

Network structures - Local

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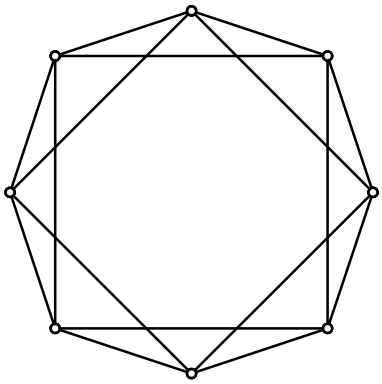

- N $(= 18)$ players are arranged on circle
- may interact only with l_i (4) most immediate neighbors
- gives $Nl_i/2$ connections
- clustering coefficient $C = 0.5$
- characteristic path length $D = 2.647$

Network structures - Random

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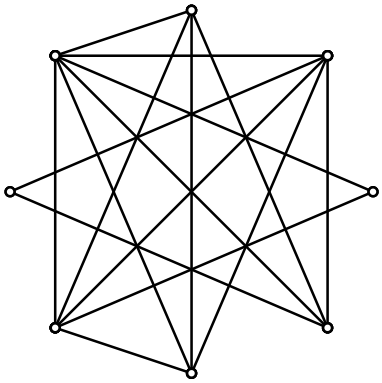

- N players 'form' random links
- each pair has equal probability to become connected
- rewiring each of the $Nl/2$ connections of the local structure → each agent is connected with an average of l other agents which can be located anywhere on the circle
- clustering coefficients $C = 0.181, 0.061, 0.180$
- characteristic path length $D = 2.033, 2.026, 2.078$

Network structures - Small world

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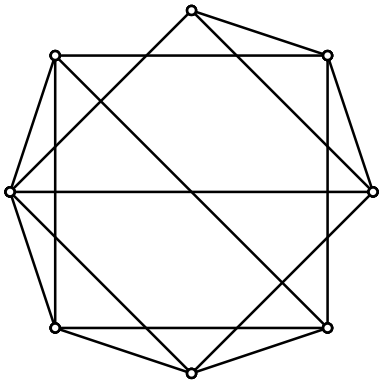

- has properties of both the local and the random structure
- N players form random links
- rewiring each of the $Nl/2$ connections of the local structure with very small probability → most agents are still connected to immediate neigbors with only few links to players far away on the circle
- clustering coefficients $C = 0.406, 0.472, 0.354$
- characteristic path length $D = 2.301, 2.458, 2.366$

Cassar's hypotheses

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- Coordination game: High clustering helps to coordinate on payoff dominant equilibrium
- Cooperation game: High clustering fosters cooperation
- Coordination game: Shorter characteristic path length leads to faster convergence towards (any) equilibrium
- Cooperation game: Shorter characteristic path length is bad for cooperation

Thus:

1. Local and small world networks exhibit most coordination on payoff dominant equilibrium; coordination is fastest in small world
2. Cooperation is highest in local network

Cassar's results - coordination

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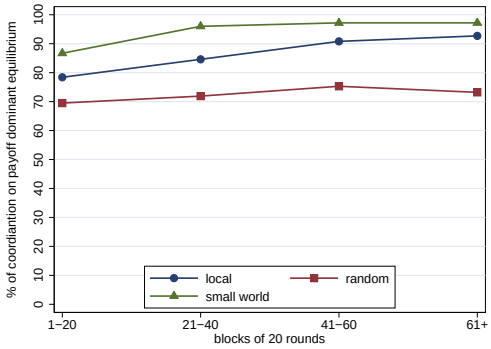
- Coordination game



- Interactions on local structures cause faster coordination than interaction on random structures
- This coordination is rather on the payoff dominant than on the risk dominant equilibrium

Cassar's results - cooperation

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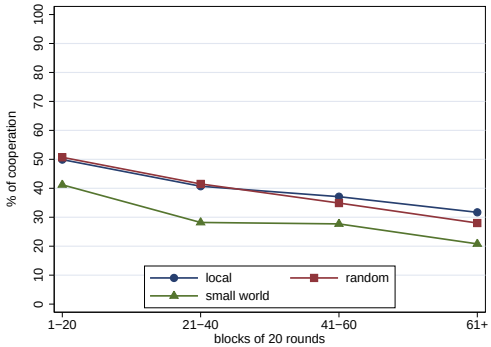
- Cooperation game



- Cooperation is hard to sustain independent of the network structure
- Cooperation does relatively best on the local structure and relatively worst in the small world

Cassar's conclusions

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- Different network structures lead to different behavior
- Small world leads to fast equilibriation
- Subjects mostly coordinate on payoff dominant equilibrium on all network structures
- Subjects are not able to sustain cooperation on any of the network structures

Caveat: Isn't any connected network in the lab a small world?

Cooperation on endogenous structures

Riedl & Ule 2005 w.i.p.

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- People are (often) free to choose with whom to interact
- Network structures become endogenous
- Examples:
  - trade network in Oceania
  - information networks
  - boycott of strikebreakers
  - stock market crowds
- Exclusion as cooperation enforcement device

Cooperation on endogenous structures - cont.

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- Interaction with important (exogenous) environmental parameters
  - outside opportunities
  - information on the network
- Simultaneous dynamics of network structure and cooperative behavior
  - up to now: mainly considered in isolation

The Network Game

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- **Basic game:** **Social dilemma** game

	Cooperate	*Defect*
Cooperate	$50, 50$	$10, 70$
Defect	$70, 10$	$30, 30$

The Network Game

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- **Extented basic game:** **Social dilemma** game with **outside option**.

	Cooperate	*Defect*	*Refuse*
Cooperate	$50, 50$	$10, 70$	v, v
Defect	$70, 10$	$30, 30$	v, v
Refuse	v, v	v, v	v, v

- $n-$players extension - embedded in an endogenous network
  - refusing to play = refusing a link
  - exclusion is possible (could be costly)
  - two-sided linking, uniform action

The Network Game

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- A **player's payoff** in the network game:

$$\pi_i(s_i, s_{-i}, L_i) = \sum_{j \in L_i} u(s_i, s_j) + \sum_{j \notin L_i} v$$

  - $L_i \longrightarrow$ neighbors of i after links are formed
  - $s_i \in \{C, D\} \longrightarrow$ decision of i in the social dilemma game

Note: mutual link formation, no costs of linking; behavior in social dilemma not neighbor contingent

(computer screen)

Experimental Design and Treatments

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- Number of players in experiment $n = 6$
- Repeated play with partners for 60 rounds
- **Four experimental treatments**: differ in **outside option value** and **information** about other players' past behavior
  - **Low** outside option: $v = 0$
  - **High** outside option: $v = 40$
  - **Max**imal information: **all** past choices of **all** others in the group
  - **Min**imal information: **only actions** of **neighbors**
- **Control treatment**: exogenously fixed full network

Theory - One-Shot Game

Standard preferences:

- **LowMax**
  - **complete network** & **full defection** in unique strict Nash equilibrium (SNE)
  - non-strict Nash equilibria with empty or partial network

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- **HighMax**
  - **empty network** in any Nash equilibrium

Proposing a link and cooperating is never part of an equilibrium strategy, regardless of the outside option value $\boldsymbol{v}$

- **FullFix**
  - **full defection** in unique Nash equilibrium

Theory - One-Shot Game

Two alternative models:

- **Levine - intentional altruism**

$$u_i(\pi) = \pi_i + \sum_{j \neq i} \frac{a_i + \lambda a_j}{1 + \lambda} \pi_j$$

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$$-1 < a_i < 1 \quad \text{and} \quad \lambda = 0.45$$

- **Fehr & Schmidt - inequity aversion**

$$u_i(\pi) = \pi_i - \frac{\alpha_i}{n-1} \sum_j \max\{\pi_j - \pi_i, 0\} - \frac{\beta_i}{n-1} \sum_j \max\{\pi_i - \pi_j, 0\}$$

$$0 \leq \beta_i < 1 \quad \text{and} \quad \beta_i \leq \alpha_i$$

Theory - One-Shot Game

Levine - intentional altruism: (Levine's estimate of $a_i < 0.5$)

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- **LowMax**
  - complete network & cooperation in SNE $\Rightarrow$ coops' *average* $a_i \geq 0.5$
  - non-strict Nash equilibria with empty or partial network & cooperation only if $a_i \geq 0.5$ for some i
  - $a_i < 0.5 \Rightarrow$ **full defection** & **complete network** in SNE
- **HighMax**
  - sub-networks of cooperators with *average* $a_i \geq 0.5$
  - $a_i < 0.5 \Rightarrow$ **empty network**
- **FullFix**
  - cooperation $\Rightarrow$ coops' *average* $a_i \geq 0.5$
  - $a_i < 0.5 \Rightarrow$ **full defection**

Theory - One-Shot Game

Fehr & Schmidt - inequity aversion: FS's estimate of $\beta_i \leq 0.6$

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- **LowMax**
  - complete network & cooperation in SNE $\Rightarrow$ *each* $\beta_i > 0.7$
  - partial cooperation in some network in SNE $\Rightarrow$ coop's $\beta_i \simeq 1$
  - NE's with empty or partial network & cooperation $\Rightarrow$ coop's $\beta_i \simeq 1$
  - $\beta_i \leq 0.6 \Rightarrow$ **full defection** & **complete network** in SNE
- **HighMax**
  - clique (sub-network) of cooperators *each* with $\beta_i > 0.7$ in SNE
  - $\beta_i \leq 0.6 \Rightarrow$ **empty network**
- **FullFix**
  - cooperation $\Rightarrow$ *each* $\beta_i > 0.7$
  - $\beta_i \leq 0.6 \Rightarrow$ **full defection**

Theory - Repeated Game

Assuming parameter estimates of Levine and Fehr & Schmidt:

- **LowMax**
  - **All models** - intuitive: complete network and full defection in all rounds; but "Folk Theorem"

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- **HighMax**
  - **All models** - empty network in all rounds
- **FullFix**
  - **All models** - full defection in all rounds

Incomplete information models → multiplicity of equilibria

Let the data speak!

Experimental Treatments and Procedures

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Experimental treatments (# of groups)		
Information:	Maximal	Minimal
$v = 0$	I: LowMax (6)	II: LowMin (6)
$v = 40$	III: HighMax (7)	IV: HighMin (8)
V: FullFix (5)		

- Eleven sessions with 192 subjects
- Each session took approximately two hours
- Average earning per subject: 24.12 Euro
- Computerized experimental sessions at CREED laboratory

Experimental Results

A snapshot of what happened. "ExclThenCoop(S6G2HighMax)"

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Experimental Results

- **Cooperative choices** - All rounds

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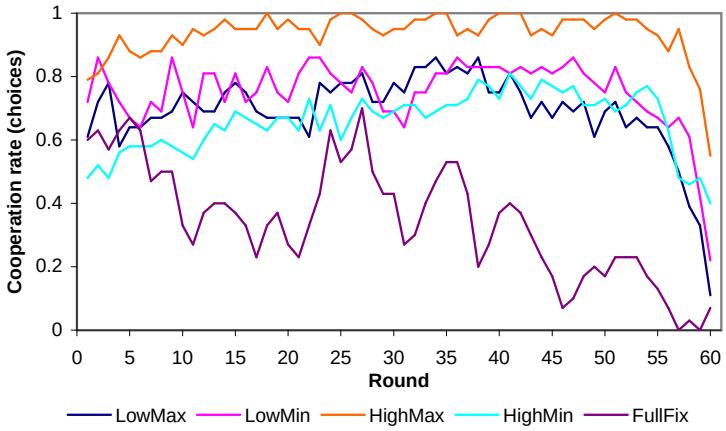

Experimental Results

Short Summary - Cooperative Behavior

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- Compared to the exogenous network treatment (FullFix) the action choices in the treatments with **endogenous network formation** are significantly **more cooperative** and exhibit significantly **more stability**.

Endogenous network formation seems to be a powerful mean for promoting *and* stabilizing cooperation at a high level

Experimental Results

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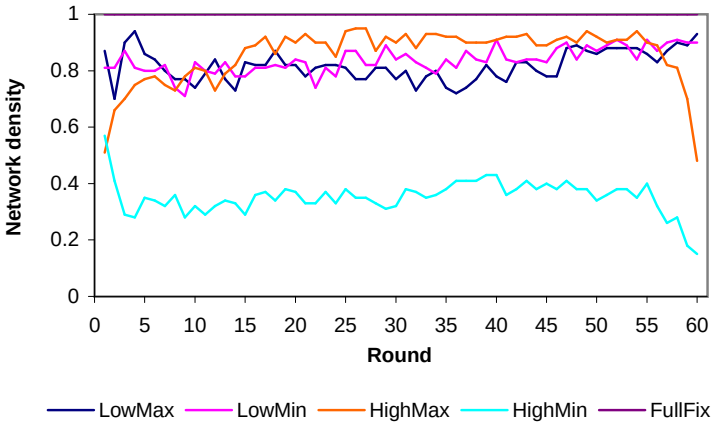
- **Network structures - network densities**: established links as a fraction of potential links.



viewer[2Excluded(S7G2HighMin)]

Experimental Results

- **Network structures**: two 'typical' average social structures.

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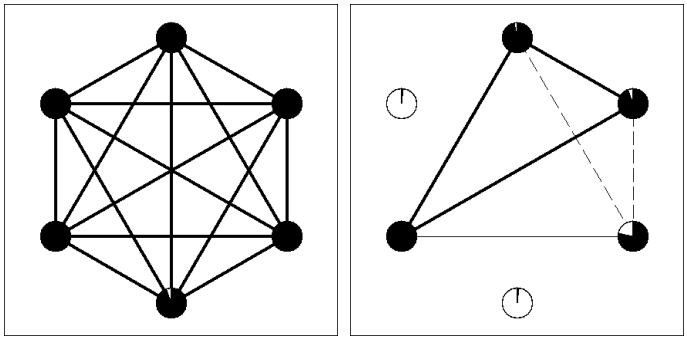

(a) HighMax(gr.6) (b) HighMin(gr.2)

Experimental Results

- **Network structures - proposed links: defectors are excluded**

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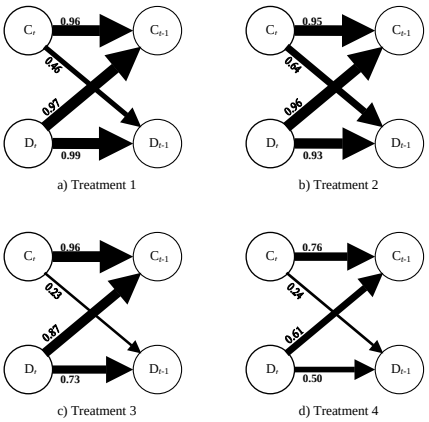

a) Treatment 1 b) Treatment 2

c) Treatment 3 d) Treatment 4

Experimental Results

Short Summary - Network Structure

- Intending cooperators are much more likely to propose links to previous period cooperators than to previous period defectors.

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- Cooperators exclude defectors more often when exclusion is cheap (high outside option) then when it is more costly (low outside option).
- Defectors try to link to everybody.
- With high outside option and low information isolation of early round defectors occurs.

Reconciling the Behavioral Dynamics

A simple model of Adaptive Play

- Use simple heuristics
- Look only two steps ahead
- Selfish, altruistic, or inequity averse
- Consider 4 possible heuristics:

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	Always link	*Exclude defectors*
Cooperate	CA	CE
Defect	DA	DE

- Updating: strategy which maximizes payoff for next two rounds; but random errors
- Use computer simulations

Adaptive play - Purely selfish players

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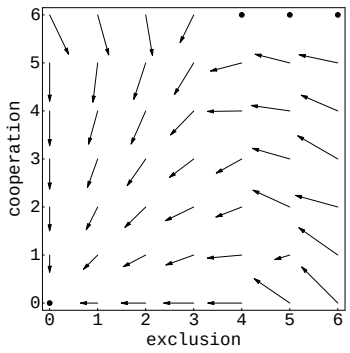
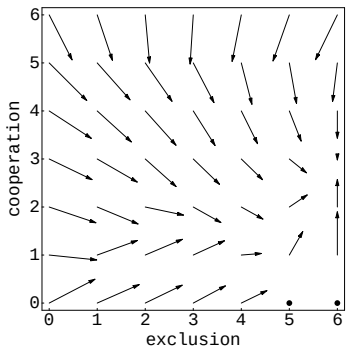
$o = 0$



$coop = 4\%$

$o = 40$



$coop = 36\%$

Adaptive play - Intentional altruists

Intentional altruists ($a_i = 0.453$) looking ahead

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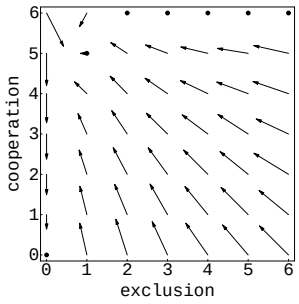
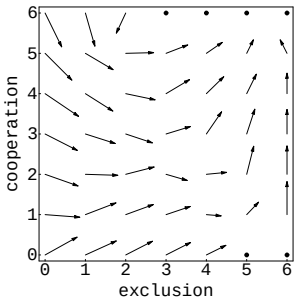
$o = 0$



$coop = 37\%$

$o = 40$



$coop = 94\%$

Model of adaptive play - Shortsighted players

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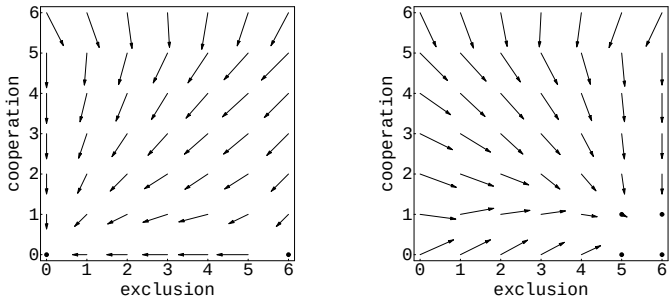
Intentional altruists ($a_i = 0.453$) myopic

$o = 0$ $o = 40$



$coop = 4\%$ $coop = 13\%$

Note - The role of mutual linking

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- **Cooperative choices**: fraction of players who choose to cooperate (with 1-sided link formation).