# Efficient Coordination in Weakest Link Games through Freedom of Partner Choice

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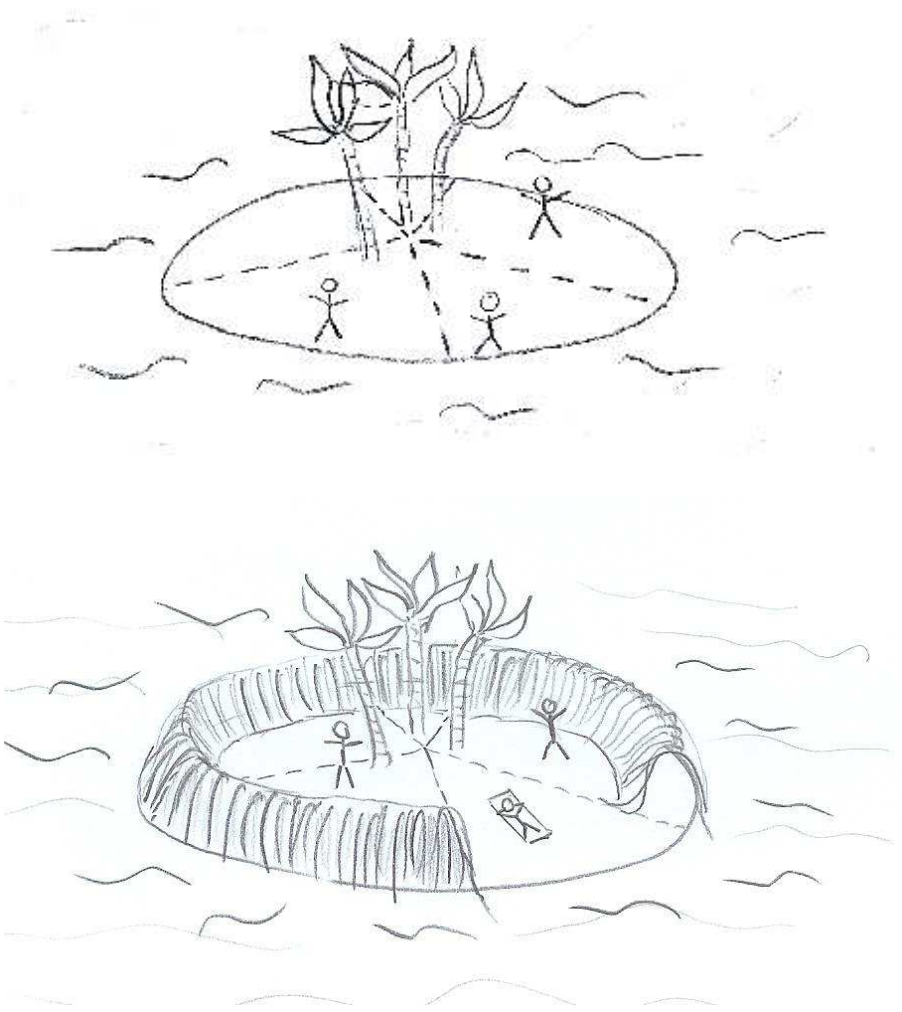
– Behavioral and Experimental Economics Seminar –

# Weakest Links - Examples.

## Hirshleifer's (1983) flat island



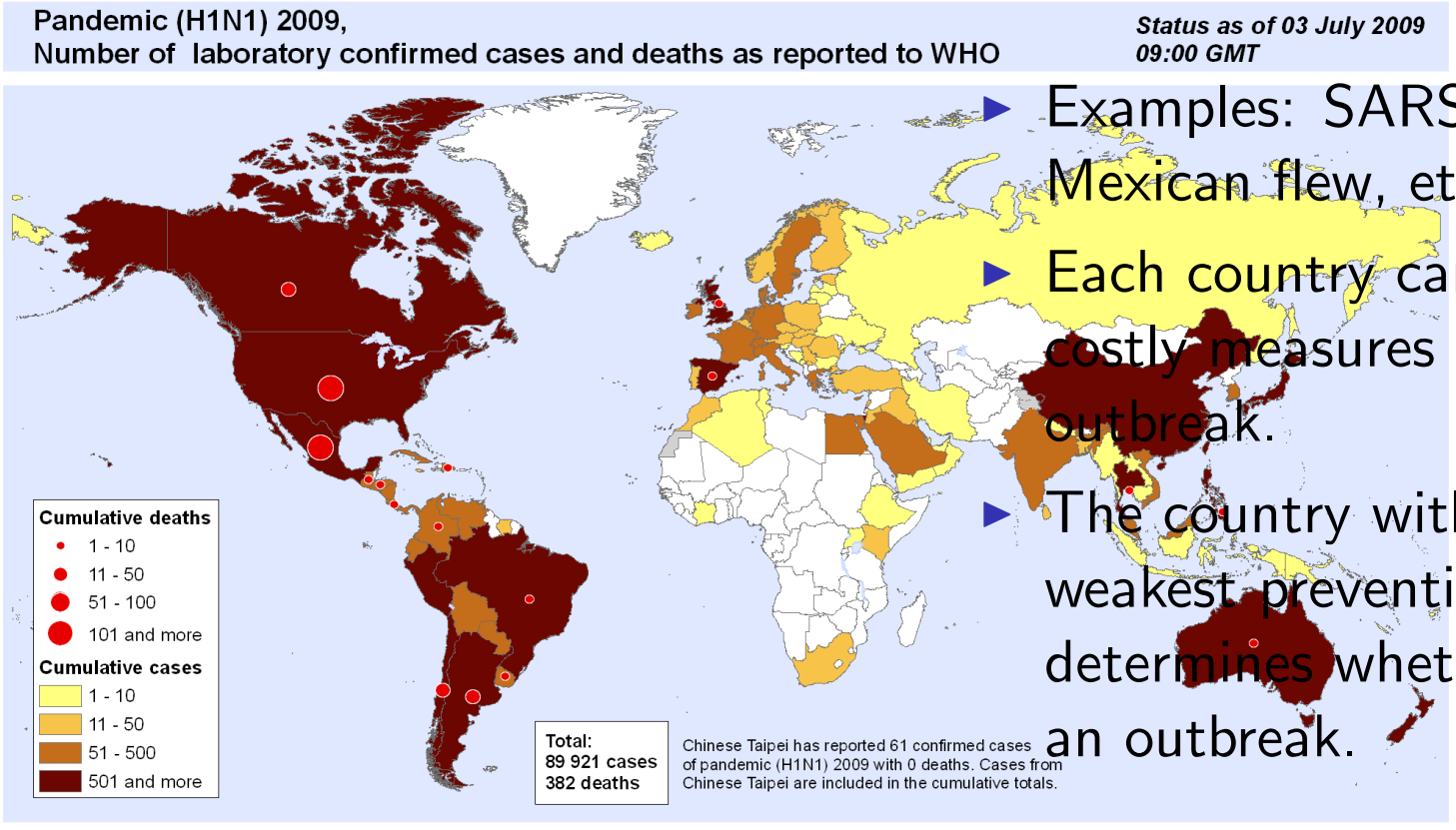
- Low-lying flat island Anarchia
  - Each inhabitant owns a sector.
  - To protect from floods each has to build a dike on his/her sector.
  - The lowest dike determines the degree of protection.
- If coordinaton fails outcomes can be disastrous.

# Weakest Links - Examples

## Disasters.

# Weakest Links - Examples.

## Spread of a disease.




- Examples: SARS, AIDS, Mexican flew, etc.
- Each country can invest in costly measures to prevent outbreak.
- The country with the weakest prevention mainly determines whether there is an outbreak.

# Weakest Links.

## More examples.

- Computer network

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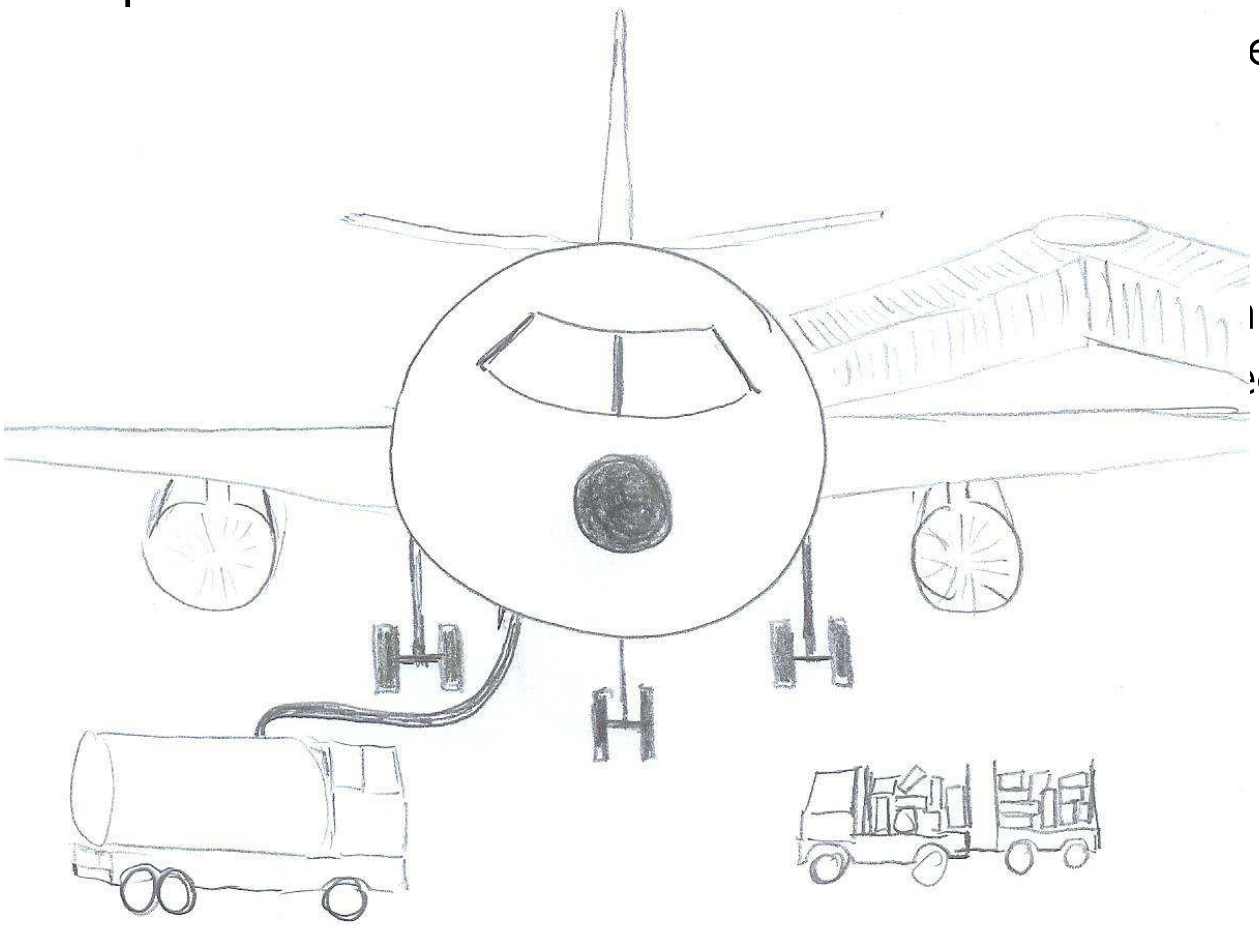

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- Airport Security

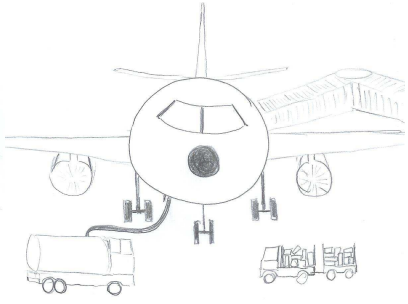
# Weakest Links.

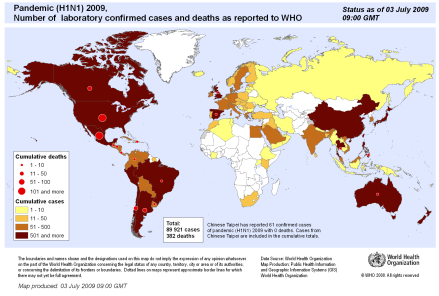
## Common Features.

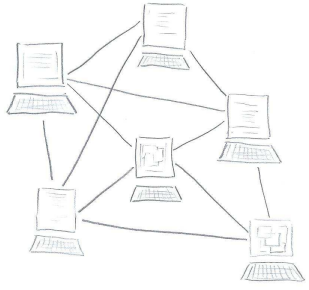
- Coordination problem.
- Individually and collectively 'optimal' to provide 'high effort'.
  - All anarchists build high dikes.
  - Countries invest in preventive measures (airport security, disease programs).
  - ICT administrators care for high computer security.
  - All ground crews work at high accuracy and speed.
- A single deviation to 'less effort' causes welfare loss for all (including him-/herself). **No** social dilemma!
- Examples can be captured by the Minimum Effort Game.

# Weakest Links.

## A Second Look at Examples.





- Players are bound to their neighborhood.
- Strategic possibilities are limited to the adaption of own effort.

- Players are **not** bound to their neighborhood.
  - Countries may discourage/forbid travel and/or restrict entrance.
  - ICT administrators may deny access from other computers.
- Exclusion/Avoidance becomes an additional strategic option.

# Weakest Links.

## A Last Example.

- Stability and Growth Pact of the European Union.
  - Stability pact does not foresee the exclusion of a member.
  - Meanwhile some people would like to have it.


*"In the future, we need an entry in the [Lisbon] Treaty that would make it possible, as a last resort, to exclude a country from the Euro zone if the conditions are not fulfilled again and again over the long term." (March 17, 2010)*

# Research Question & Hypothesis.

- **Question**: Does neighborhood choice lead to more efficient outcomes in the weakest link (minimum effort) game?
- **Hypothesis**: Yes!
- **Reason**: The extended strategy set helps overcoming strategic uncertainty.
- **Necessity**: Existence of people that are ready to costly exclude/avoid 'inefficient players'.

# Minimum Effort Game in Fixed Groups.

- 8 players have to provide 'effort' to produce joint output
- Lowest effort determines total output (earnings) for all

$$20 \times \min_{j \in N(i)}\{e_j\} - 10e_i + 60$$

| | | minimum effort in group | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| | 7 | 130 | 110 | 90 | 70 | 50 | 30 | 10 |
| | 6 | | 120 | 100 | 80 | 60 | 40 | 20 |
| effort | 5 | | | 110 | 90 | 70 | 50 | 30 |
| of $i$ | 4 | | | | 100 | 80 | 60 | 40 |
| | 3 | | | | | 90 | 70 | 50 |
| | 2 | | | | | | 80 | 60 |
| | 1 | | | | | | | 70 |

- Multiple equilibria with different surplus levels (Pareto ranked)
- Stochastically stable equilibrium $\Rightarrow$ All choose lowest effort.

# Minimum effort game - Results so far.

- First formulated by Bryant (1983) as macroeconomic (Keynesian) coordination game
- First experiment by Harrison & Hirshleifer (JPE, 1989), Van Huyck, Battalio, & Beil (AER, 1990)
  - efficient for very small groups, but
  - devastating results regarding efficiency for larger groups
- Wave of experiments testing robustness of result
  - large efficiency gains (Brandts & Cooper, 2006)
  - long time horizon (Berninghaus & Erhart, 1998)
  - cheap talk (Blume & Ortmann, 2007)
  - public advice (Chaudhuri, Schotter, & Sopher, 2009)
  - being Danish (Engelmann & Normann, 2009)
  - ... (see, e.g., Devetag & Ortmann, 2007)

# Minimum effort game - Results so far (cont').

- Group size

TABLE 2—DISTRIBUTIONS OF FIFTH-PERIOD GROUP MINIMA IN VARIOUS 7-ACTION MINIMUM-EFFORT STUDIES
(*1 = inefficient; 7 = efficient*)

| Minimum choice in fifth period | | | | | | | Group size | Number of groups | Source |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | | | |
| 86% | 3% | 3% | 3% | 0% | 0% | 5% | 2 | 37 | VHBB, CK |
| 18% | 4% | 0% | 11% | 15% | 15% | 37% | 3 | 27 | KC, CK |
| 0% | 0% | 0% | 0% | 10% | 10% | 80% | 6 | 10 | KC |
| 0% | 0% | 0% | 0% | 0% | 0% | 100% | 8 | 5 | CSS |
| 0% | 0% | 0% | 0% | 0% | 0% | 100% | 9 | 2 | CC |
| 0% | 0% | 0% | 0% | 0% | 0% | 100% | 14–16 | 7 | VHBB |

*Sources:* Van Huyck et al., 1990 (VHBB); Camerer and Knez, 2000 (CK); Knez and Camerer, 1994 (KC); Gerard P. Cachon and Camerer, 1996 (CC); Chaudhuri et al., 2001 (CSS).

- For group sizes larger (or equal) 8 coordination on **worst** equilibrium!
- Letting groups grow in size up to $n = 12$ helps (somewhat) (Weber, 2006).

# Minimum effort game with neighborhood choice.

- **Implementation:** take standard minimum effort game *add* neighborhood choice.
- Formally: each player decides simultaneously and independently
  - with whom to interact (interaction takes place only if other side also proposes to interact) *and* which effort level to choose.
  - Payoff of a player $i$ with neighbors $j \in N(i)$ and neighborhood size $|N(i)|$:

    $$\boxed{\frac{|N(i)|}{n-1}\left[20 \times \min_{j \in N(i)}\{e_j\} - 10e_i + 60\right]}$$

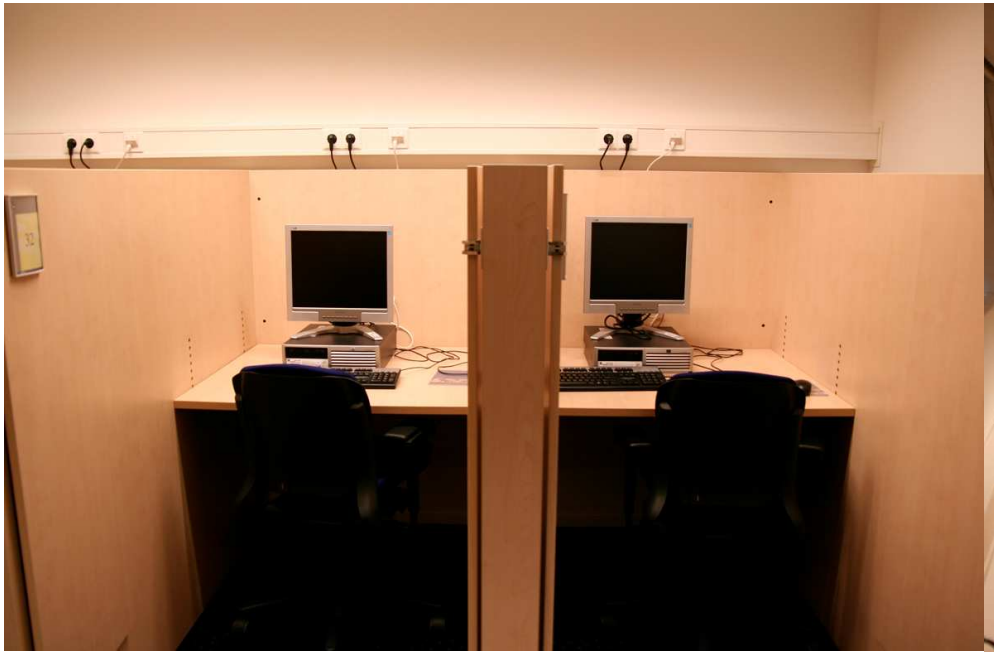
    Not playing earns nothing, playing earns positive amount.
    $N(i) = n - 1$ for all $i$: as in fixed group game, same payoff.
- This game has millions of equilibria!
- Stochastic stability $\Rightarrow$ complete network with lowest effort level.

# Design and Procedures.

| **Control treatment** | **Experimental treatment** |
|---|---|
| 8 subjects | 8 subjects |
| Minimum effort game in | Minimum effort game with |
| fixed neighborhood (all others) | freely chosen neighborhood |
| repeated for 30 rounds | repeated for 30 rounds |
| full information | full information |
| about past behavior | about past behavior |
| 8 independent groups | 10 independent groups |
| duration: ca. 55 minutes | duration: ca. 85 minutes |
| average earnings: €12,- | average earnings: €17,- |
| all computerized using z-tree (Fischbacher 2007) | |
| BEElab Maastricht University | |

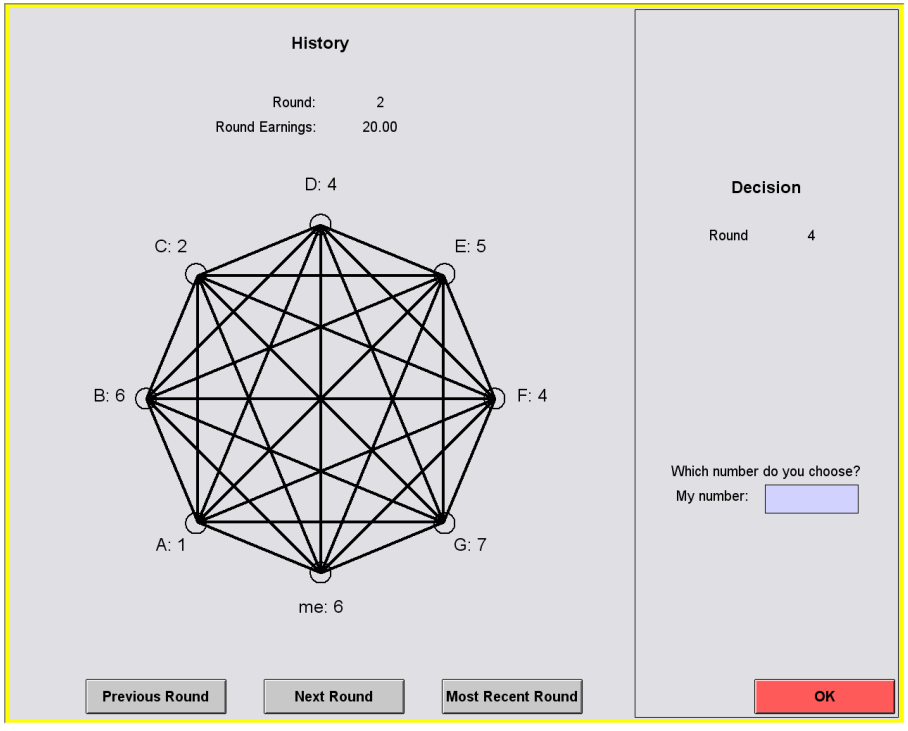
# BEElab Maastricht University.

Behavioral and Experimental Laboratory
`http://www.fdewb.unimaas.nl/beelab/`.

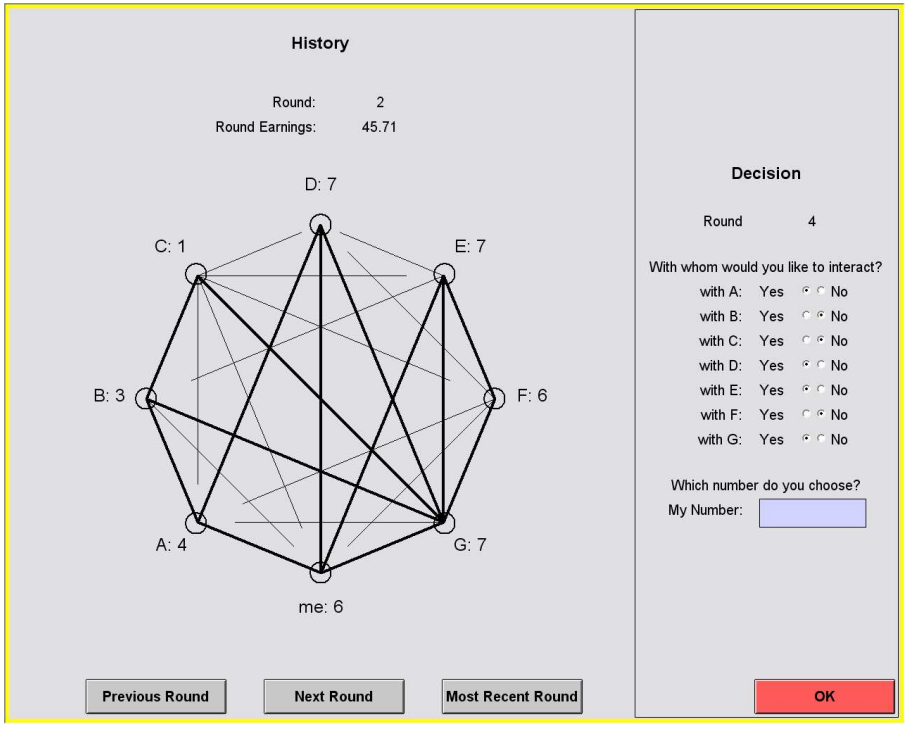


# Treatments - Computer screens.

## Fixed group



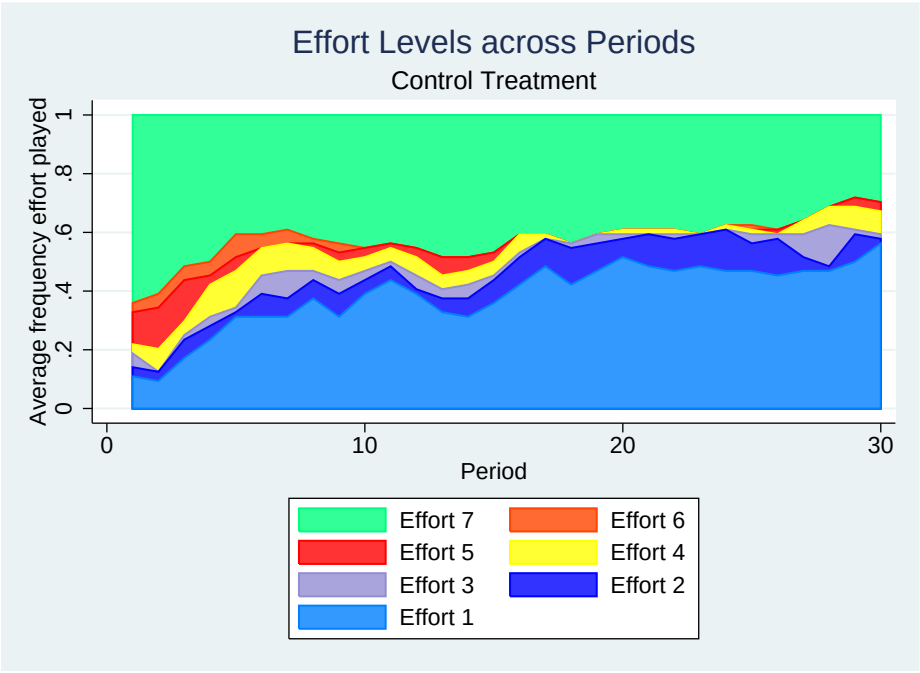

## Neighborhood choice



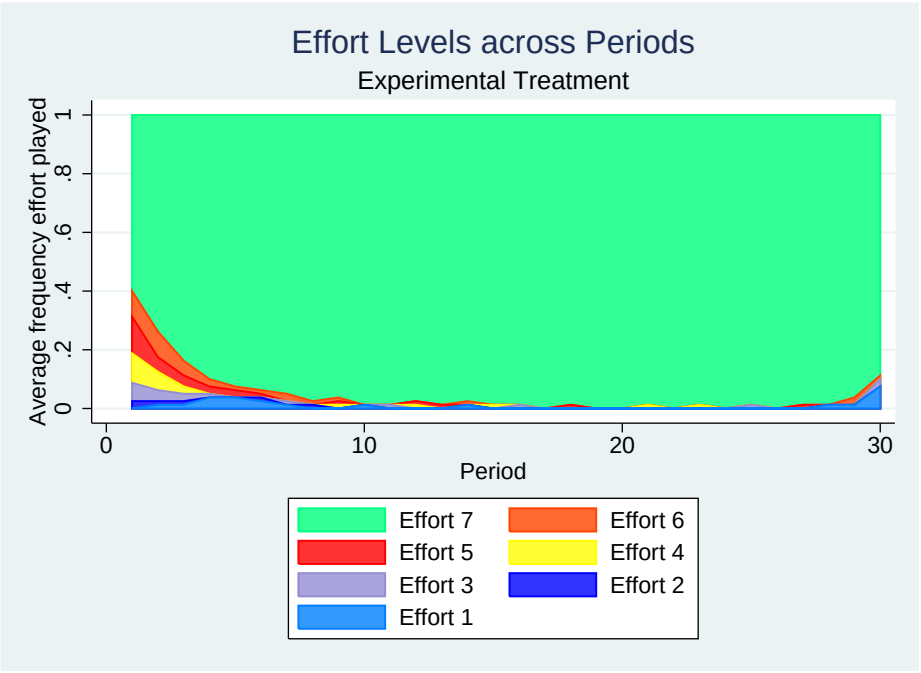
# Distribution of Effort Levels over Time.

## Fixed Group vs. Neighborhood Choice.

### Fixed group




### Neighborhood choice




- **Fixed group:** frequency of lowest effort level increases and the frequency of highest effort level decreases.
- **Neighborhood choice:** almost full converge to 100 percent frequency of highest effort level.

# Dynamics of Effort Levels over Time.

## Fixed Group vs. Neighborhood Choice.

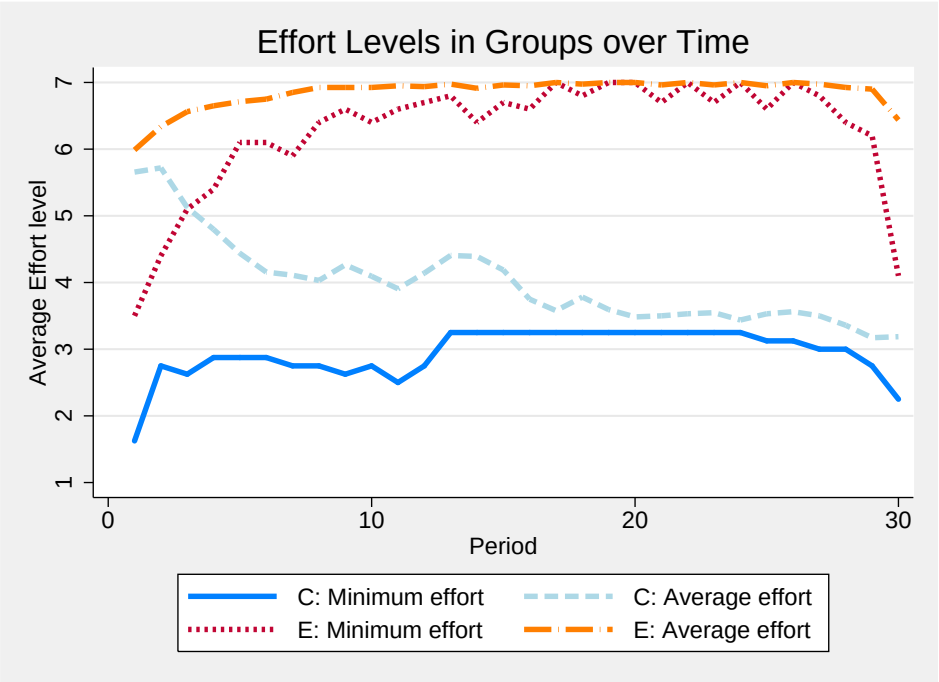
Table: Spearman rank order correlation coefficients between rounds and average frequency of effort levels.

| baseline treat. | | | | | | | |
|---|---|---|---|---|---|---|---|
| effort level | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| coefficient | 0.88 | 0.39 | −0.19 | −0.44 | −0.54 | −0.73 | −0.82 |
| *p*-value | .000 | .033 | .309 | .015 | .002 | .000 | .0001 |
| neighborhood treat. | | | | | | | |
| effort level | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| coefficient | −0.25 | −0.60 | −0.37 | −0.39 | −0.64 | −0.58 | 0.59 |
| *p*-value | .184 | .000 | .043 | .034 | .000 | .001 | .001 |

skip averages

# Effort Levels over Time.

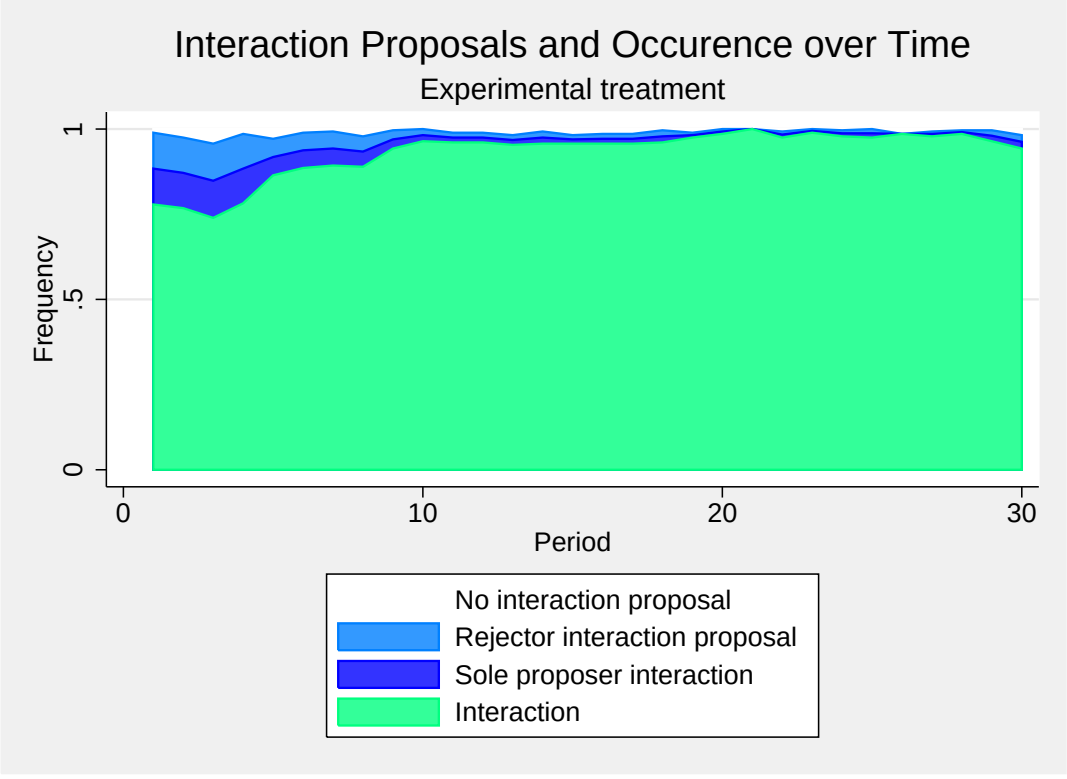
## Average efforts and average minimum efforts.




- **Fixed group:** average minimum effort is low and average effort decreases towards it.
- **Neighborhood choice:** average and average minimum effort are reaching maximally possible effort level.

# Frequency of Interaction and Interaction Proposals.

## Actual and proposed interaction over time.




- Actual interaction frequency significantly increases over time.

# Exclusion.

- Analysis of dyadic relationships over time.
  - Is getting excluded a consequence of low effort?
  - Who excludes whom?
  - Does exclusion help?
  - Do excluded players change behavior?
- Analyze behavior in

| | |
|---|---|
| period $t-1$ | How do $i$ and $j$ behave? Compare $e_i^{t-1}$ and $e_j^{t-1}$. |
| period $t$ | Does $j$ exclude $i$? |
| period $t+1$ | How does $i$ react? Compare $e_i^{t+1}$ with $e_i^{t-1}$. |

# Reasons for and Response to Exclusion.

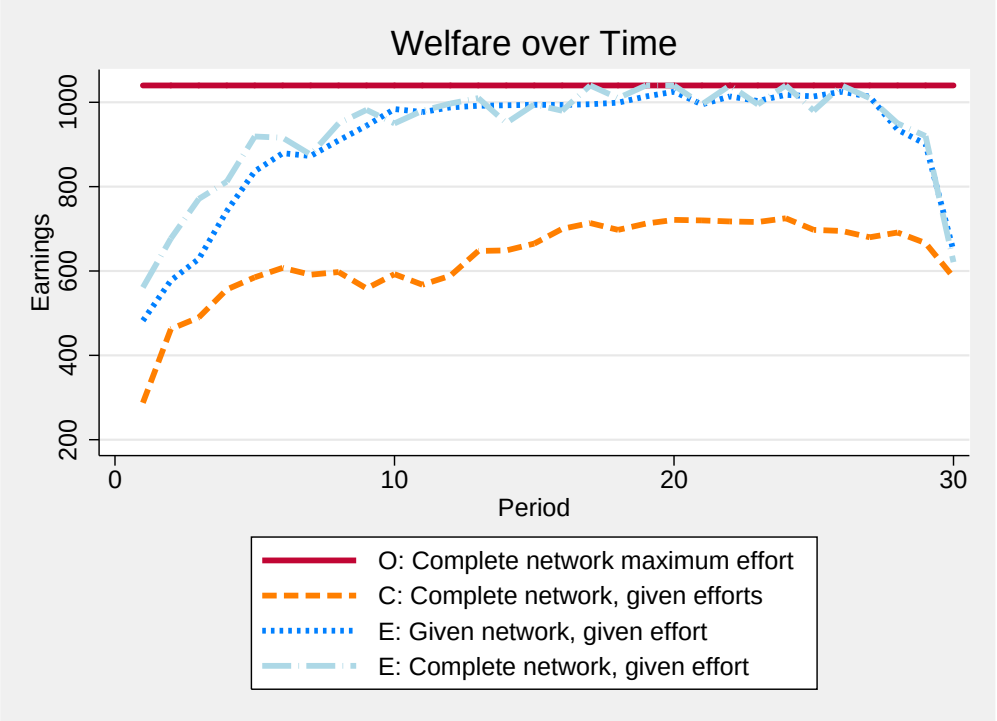
| Round | Action | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $t-1$ | $i$'s effort $e_i \geq e_j$ | | | $i$'s effort $e_i < e_j$ but $e_i > \min_{k \in N_j}\{e_k\}$ | | | $i$'s effort $e_i < e_j$ and $e_i = \min_{k \in N_j}\{e_k\}$ | | |
| $t$ | $j$ excluded $i$ excl. rate: 0.6% cases: 84/14738 | | | $j$ excluded $i$ excl. rate: 23.6% cases: 21/89 | | | $j$ excluded $i$ excl. rate: 38.5% cases: 105/273 | | |
| $t+1$ | $i$'s reaction | | | $i$'s reaction | | | $i$'s reaction | | |
| | | $j \in I_i$ | $j \notin I_i$ | | $j \in I_i$ | $j \notin I_i$ | | $j \in I_i$ | $j \notin I_i$ |
| | $e_i \uparrow$ | 11.8% (9) | 2.6% (2) | $e_i \uparrow$ | 71.4% (15) | 9.5% (2) | $e_i \uparrow$ | 61.6% (61) | 10.1% (10) |
| | $e_i =$ | 68.4% (52) | 14.4% (11) | $e_i =$ | 4.8% (1) | 4.8% (1) | $e_i =$ | 18.2% (18) | 0.0% (0) |
| | $e_i \downarrow$ | 1.3% (1) | 1.3% (1) | $e_i \downarrow$ | 9.5% (2) | 0.0% (0) | $e_i \downarrow$ | 10.1% (10) | 0.0% (0) |

- Exclusion takes place and it induces low effort providers to increase effort level.

skip welfare

# Welfare effects.

## Development of earnings over time.




- **Fixed group:** welfare increases but levels out at 50 percent of maximum efficiency.
- **Neighborhood choice:** welfare increases up to maximally achievable welfare.

# Large groups treatment.

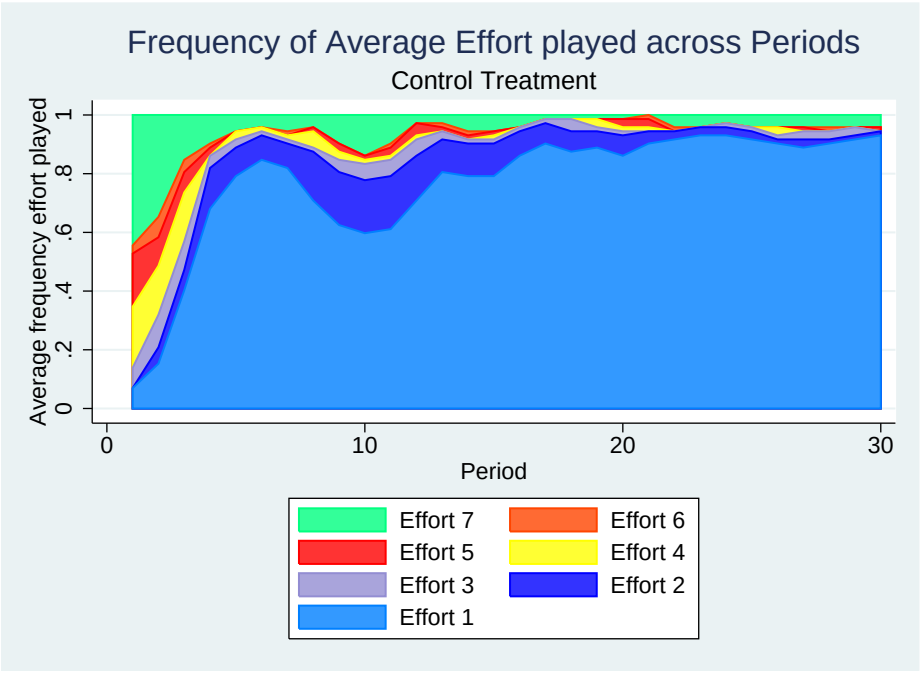
## Design and Procedures.

| **Control treatment** | **Experimental treatment** |
|---|---|
| **24** subjects | **24** subjects |
| Minimum effort game in | Minimum effort game with |
| fixed neighborhood (all others) | freely chosen neighborhood |
| repeated for 30 rounds | repeated for 30 rounds |
| full information | full information |
| about past behavior | about past behavior |
| 3 independent groups | 3 independent groups |

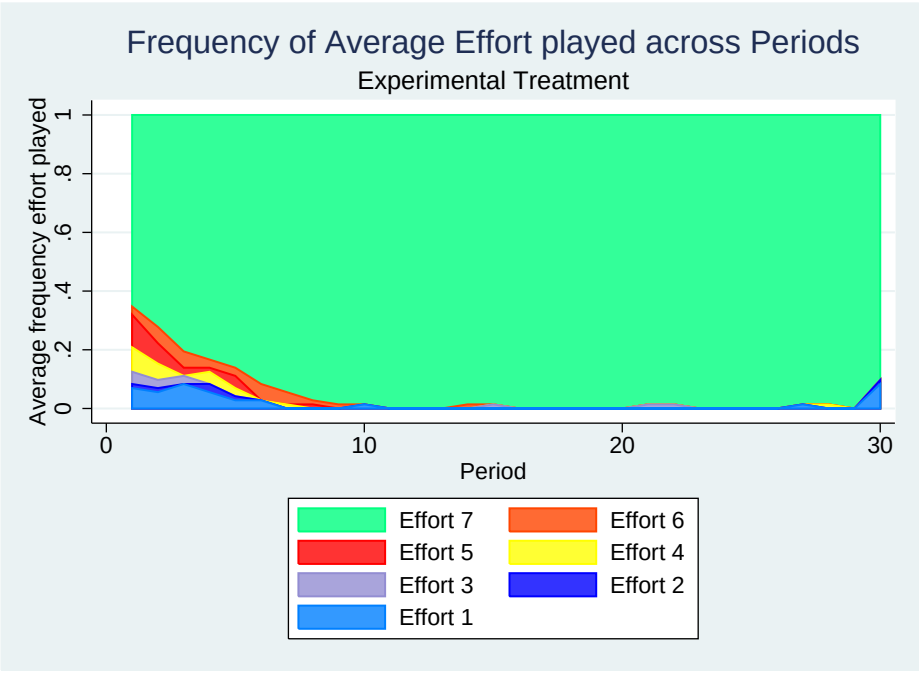
# Distribution of Effort Levels over Time.

## Fixed Group vs. Neighborhood Choice.

### Fixed group




### Neighborhood choice

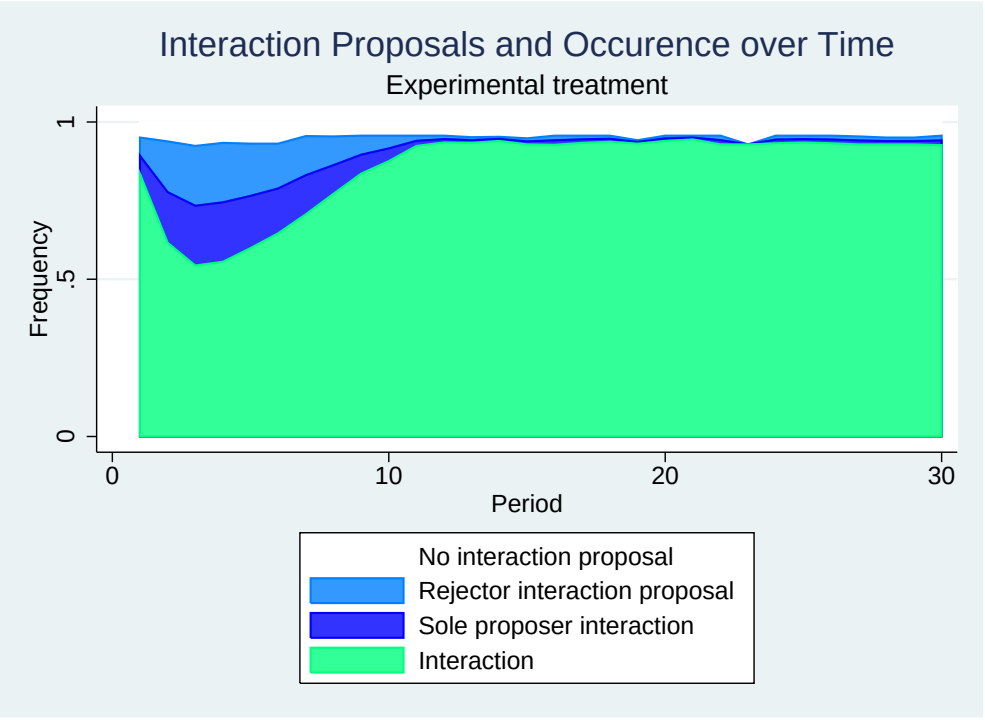



- **Fixed group:** over time almost all subjects choose the **lowest** possible **effort level**.
- **Neighborhood choice:** almost full converge to 100 percent frequency of highest effort level (except 1 subject out of 72).

▸ skip interaction

# Frequency of Interaction and Interaction Proposals.

## Actual and proposed interaction over time.




- Convergence to complete interaction with exclusion in the beginning.
- Exclusion works similar as in medium sized groups.

# Summary and Conclusion.

- Existing work on weakest link problems ignores the possibility of neighborhood choice ...
  ... in consequence it draws a too sober picture.
- Have shown that **freedom to choose neighborhood** is powerful mean to reach **efficient outcomes** in medium sized and large groups.
- Importantly, in 'equilibrium' exclusion may not be observed!
- Regarding motivating examples:
  - Without neighborhood choice: regulation is likely needed
  - With neighborhood choice: regulation is likely not needed.

# Open issues remain ...

- Theoretically:
  - How can we explain the observed behavior?
  - Costly exclusion as a coordination device?
- Experimentally:
  - ... costs of exclusion and avoidance
  - ... the role of information
  - ... number of rounds
  - ... decreasing/increasing returns to scale of neighborhood size
  - ...

Thank you for your attention!