Neighborhood Choice and Efficient Coordination

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Introduction & Motivation

- Coordination - important problem ...
  - ... firms & organizations
  - ... voluntary exchange
  - ... economy, in general
  - ... social life
- Coordination - often tacit
- Strong experimental evidence for coordination failure or coordination on inefficient equilibrium

  Van Huyck, J. B., Battalio, R.C., and Beil, R.O. (1990,1991); Cooper, R., De Jong, D., Forsythe, R., and Ross, T. (1989,1990)
- Why do we see so much seemingly coordinated behavior in the outside-lab world? Is all this inefficient?

Notes:

Early experimental studies (the seminal works) on coordination failure:

Van Huyck, J. B., Battalio, R.C., and Beil, R.O. (1990). Tacit Coordination Games, Strategic Uncertainty, and Coordination Failure. The American Economic Review, 80, 234-248.

Van Huyck, J. B., Battalio, R.C., and Beil, R.O. (1991). Strategic Uncertainty, Equilibrium Selection, and Coordination Failure in Average Opinion Games. The Quarterly Journal of Economics, 106, 885-911.

Cooper, R., De Jong, D., Forsythe, R., and Ross, T. (1989). Communication in the Battle of the Sexes Games. Rand Journal of Economics, 20, 568-587.

Cooper, R., De Jong, D., Forsythe, R., and Ross, T. (1990). Selection Criteria in Coordination Games: Some Experimental Results. American Economic Review, 80, 218-233.

Introduction & Motivation

- A couple of identified determinants for (partly) overcoming coordination failure and inefficiencies Devetag and Ortmann (2007)
  - low attractiveness of secure option,
  - low deviation costs, more rounds of play,
  - smaller group size, fixed matching,
  - pre-play communication, ...
- Interestingly, all these studies focus on fixed interaction structures.
  - Recently, R. Weber (2006) shows that exogenously increasing group sizes may help to overcome inefficiencies (in larger groups).

Notes:

Giovanna Devetag and Andreas Ortmann (2006). ”When and Why? A Critical Survey on Coordination Failure in the Laboratory”, Experimental Economics, 10, 3, 331-344.

- Lower attractiveness of the secure action relative to the risky action required for the efficient equilibrium is efficiency-enhancing (e.g., Brandts and Cooper, 2004).
- Low (zero) deviation costs are efficiency enhancing (e.g., VHBB, 1990; BSVH, 2001).
- Lower costs of experimentation such as increasing the number of rounds while keeping the overall earnings roughly the same, or refining the actions space, or some combination thereof, are efficiency-enhancing (e.g., Berninghaus and Ehrhart, 1998; Van Huyck et al., 2001).
- Lower costs of exerting effort is efficiency-enhancing (e.g., Goeree and Holt, 2005).
- Less stringent coordination requirements (i.e., a smaller group size or a less stringent order statistic) are efficiency-enhancing (e.g., VHBB, 1990; Van Huyck et al., 2001).
- Fixed matching protocols are efficiency enhancing (e.g., VHBB, 1990; Clark and Sefton, 2001; Schmidt et al., 2003).
- Repeated encounters are efficiency enhancing even under random matching schemes if the experimental design and implementation focuses subjects on deductive principles (e.g., Rankin, Van Huyck, and Battalio, 2000; see also Schmidt et al., 2003).

- Providing full informational feedback seems efficiency enhancing in small groups (e.g., Berninghaus and Ehrhart, 2001; Brandts and Cooper, 2005; but see Devetag, 2005).
- The possibility of observation of action choices, especially if paired with previous expressions of intent, is efficiency-enhancing (Duffy and Feltovich, 2002, 2005).
- Slowly growing groups that have managed to establish efficient precedents, is efficiency enhancing (Weber, 2005).
- Costly pre-play communication is efficiency-enhancing (e.g. VHBB, 1993; Cachon and Camerer, 1996).
- Costless pre-play communication is efficiency-enhancing (e.g., CDFR, 1992; Van Huyck, Gillette, and Battalio, 1992; Blume and Ortmann, 2005; Duffy and Feltovich, 2002, 2005; Bangun, Chaudhuri, Prak and Zhou, 2006).
- Higher quality of information, and common knowledge of information, are efficiency- enhancing (Chaudhuri, Schotter and Sopher 2005; see also Bangun, Chaudhuri, Prak and Zhou, 2006.)
- Loss avoidance may be efficiency-enhancing if losses are certain for a chosen action (e.g., Rydval and Ortmann, 2005; Feltovich, Iwasaki and Oda, 2005).

Introduction & Motivation

- Outside the lab we can almost always choose our interaction partners or neighbors.
- Our approach - crucial step further than Weber (2006) $\rightarrow$ **endogenize interaction structure**

  see also Corbae and Duffy (2007)
- Relation to theoretical literature on endogenous networks and coordination games

  Goyal and Vega-Redondo (2005); Jackson and Watts (2002)
- Contribution of our study is two-fold:
  - Role of neighborhood choice in overcoming coordination failure and inefficient coordination.
  - Test of recent theoretical models of coordination games played in endogenous networks.

Introduction & Motivation

Similarities and differences of the two models:

- Both models:
  - agents choose (potential) interaction partners and action in 2×2 coordination game
  - game is played with all neighbors (i.e. directly linked agents)
  - no discrimination in actions between neighbors
- Main differences:
  - GVR focus on one-sided (unilateral) linking while JW examine two-sided (mutual) linking
  - linking and action choice is simultaneous in GVR and sequential in JW

The Game

The coordination game:

Column player's choice

Row player's choice

		B	G
Row player's choice	B	a,a	d,e
	G	e,d	b,b

where

$a > e, \qquad b > d, \qquad a > b, \qquad a + d < b + e; \qquad 0 \text{ if no play.}$

- Two pure Nash equilibria that can be Pareto ranked.
  - Payoff dominant equilibrium: (B, B)
  - Risk dominant equilibrium: (G, G)
- Payoff for playing the coordination game with all neighbors: $\pi_i(s_i, s_{-i}) = \sum_{j \in N_i(g)} \pi_i(s_i, s_j)$

Experimental Game & Parameters

- Three experimental treatments (conditions):
  - I: one-sided costless link formation '1s_nc'
  - II: one-sided costly link formation '1s_c'
  - III: two-sided costless link formation '2s_nc'
- One control treatment:
  - C: fixed complete network 'base'

$n = 6$

		Column player's choice: B	Column player's choice: G
Row player's choice	B	95,95	5,90
	G	90,5	75,75

linking costs: 0 in 1s_nc and 2s_nc, 80 in 1s_c

Hypotheses

Theoretical predictions:

- *base*: One-shot - either (B,B) or (G,G); Long-run - only (G,G), i.e., risk dominant play
- *1s_nc*: (GVR) One-shot - complete network, either (B,B) or (G,G); Long-run - **complete network**, only (G,G), i.e., risk dominant play
- *1s_c*: (GVR) One-shot - either empty network or complete network and only (B,B); Long-run - **complete network**, only (B,B), i.e., payoff dominant play
- *2s_nc*: One-shot - multiple networks, either (B,B) or (G,G); Long-run - **complete network**, only (G,G), i.e., risk dominant play

Hypotheses

Behavioral hypotheses:

- *base*: mainly (G,G), i.e., risk dominant play
- *1s_nc*: **complete network**, mainly (G,G), i.e., risk dominant play
- *1s_c*: highly **incomplete network**, mainly (B,B), i.e., payoff dominant play
  coordination failure in network formation
- *2s_nc*: **complete network** mainly (B,B), i.e., payoff dominant play
  efficiency enforcement

Notes:

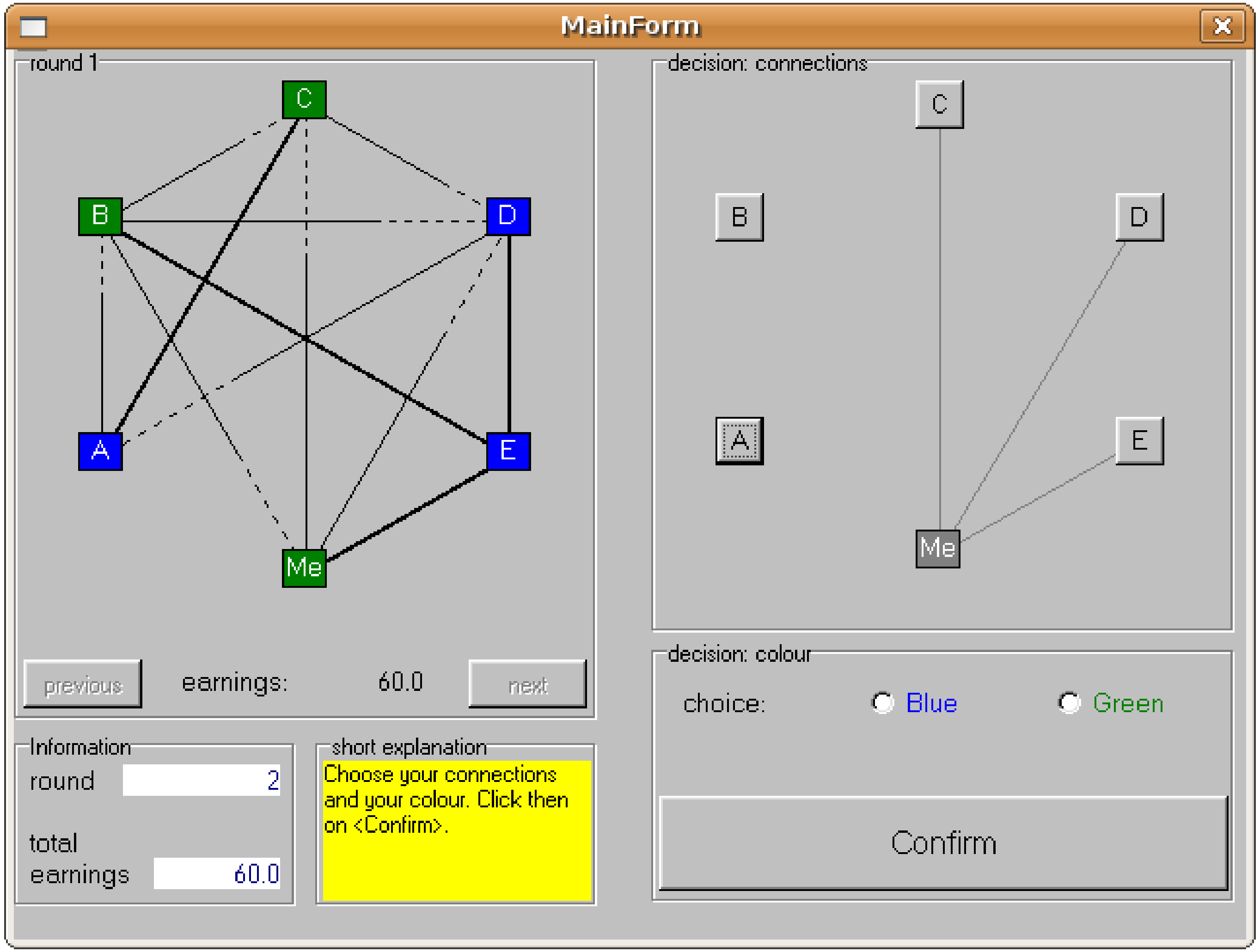
Experimental Design & Procedures

Structure of an experimental session

1.	Circle and ellipse test $\rightarrow$ measuring *fairness & efficiency attitudes*
2.	Network & coordination game (Part I); 30 rounds
3.	Network & coordination game (Part II); 30 rounds
4.	Ten-paired lottery test $\rightarrow$ measuring *risk attitudes*
5.	Questionnaires $\rightarrow$ measuring *personality traits & demographics*

Experiment Stages - Screen Shots

Network & coordination game



Experimental Design & Procedures

- Computerized at BEElab at Department of Economics, Maastricht University
- In total 210 subjects participated in 12 sessions; none participated twice

Treatment		# groups	# sessions	avg. earnings
(C)	base	9	3	26.93
(I)	1s_nc	9	3	30.05
(II)	1s_c	8	3	17.78
(III)	2s_nc	9	3	28.80

- Duration of a typical session: about 2 hours

Notes:

Check duration of session and earnings

Results: Interaction Density

Interaction density (part 1)

Treatments		t = 1 Frequency	t = 1-30 Frequency	t = 5-25 Frequency
(C)	base	1.0000	1.0000	1.0000
(I)	1s_nc	1.0000	1.0000	1.0000
(II)	1s_c	0.6500	0.6194	0.6246
(III)	2s_nc	0.8593	0.9262	0.9245

- Interaction densities differ across treatments! They are:
  1. Highest when the interaction can be costlessly initiated one-sided.
  2. Second highest when interaction is costless but needs mutual agreement.
  3. Lowest if interaction can be initiated one-sided but is costly.

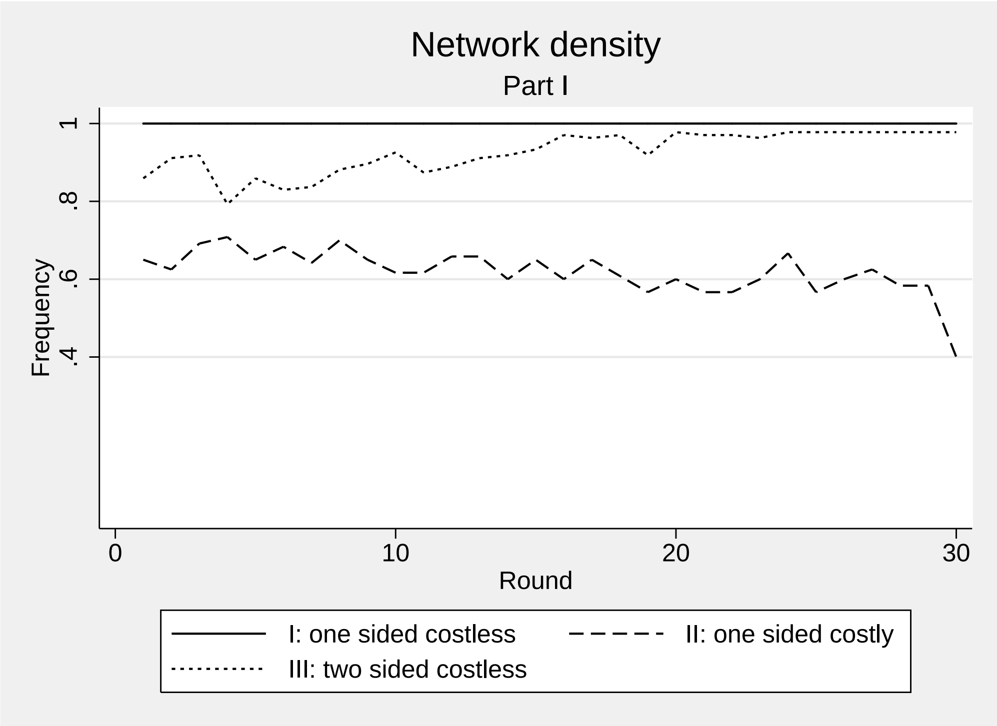
Interaction density (part 2)

Treatments		t = 1 Frequency	t = 1-30 Frequency	t = 5-25 Frequency
(C)	base	1.0000	1.0000	1.0000
(I)	1s_nc	1.0000	1.0000	1.0000
(II)	1s_c	0.6250	0.6133	0.6159
(III)	2s_nc	0.9259	0.9768	0.9806

Notes:

Results: Interaction Density

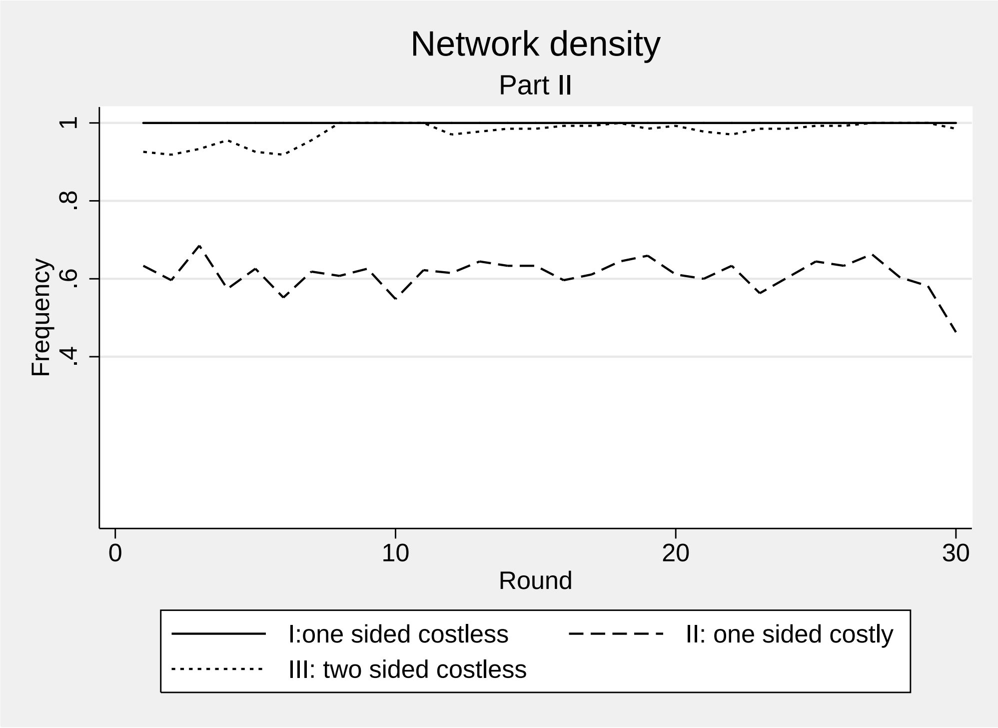
Dynamics of interaction densities (part 1)



- In 1s_nc interaction densities are 100% throughout all rounds!
- In 2s_nc interaction densities are significantly increasing and reach 100% in later rounds.
- In 1s_c interaction densities significantly decrease over rounds. Suggests increasing second-order coordination problem!

Notes:

Dynamics of interaction densities (part 2)



Results: Action choices

Payoff dominant action choices (part 1)

Treatments		t = 1 Frequency	t = 1-30 Frequency	t = 5-25 Frequency
(C)	base	0.5370	0.3951	0.3898
(I)	1s_nc	0.7222	0.7315	0.7152
(II)	1s_c	0.6875	0.8701	0.8819
(III)	2s_nc	0.6481	0.8093	0.8386

- Subjects choose payoff dominant equilibrium action much more often when interaction partners can be chosen endogenously.
- First round behavior does not differ between treatments.
- Across all rounds differences between control and experimental treatments are statistically significant ($p < 0.05$, MW-test, 1-sided).

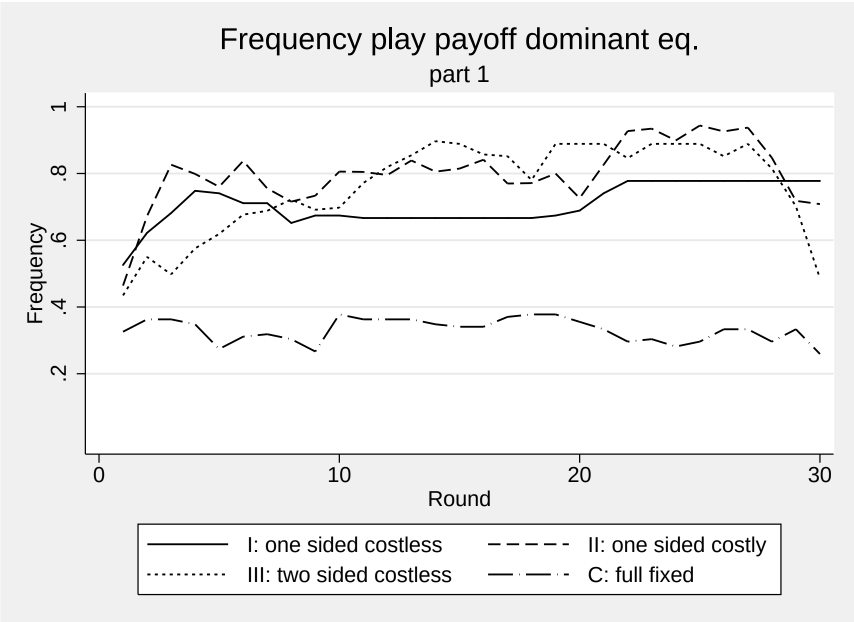
Payoff dominant action choices (part 2)

Treatments		t = 1 Frequency	t = 1-30 Frequency	t = 5-25 Frequency
(C)	base	0.5370	0.6031	0.6032
(I)	1s_nc	0.7960	0.9858	0.9991
(II)	1s_c	0.8333	0.9597	0.9791
(III)	2s_nc	0.6481	0.9623	0.9921

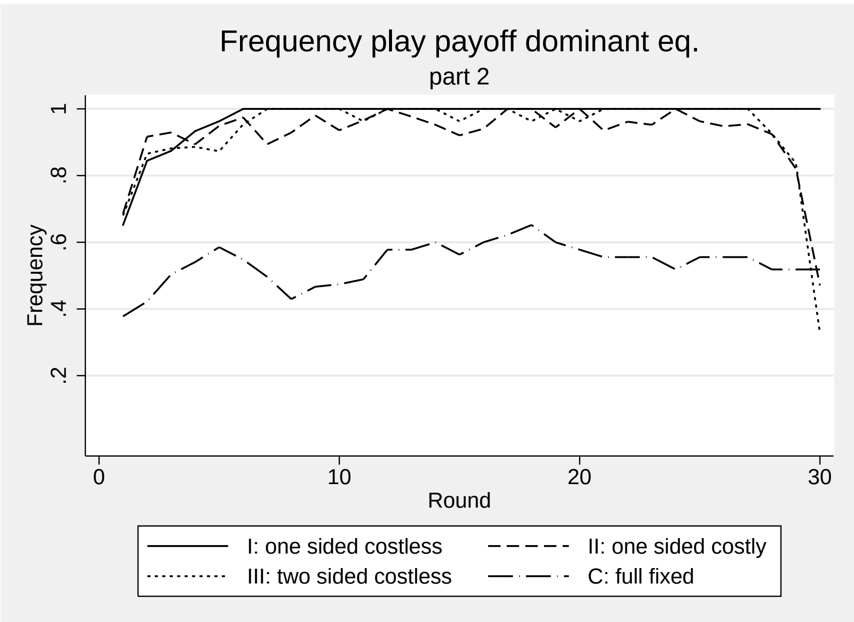
Notes:

Notes:

Dynamics of conditional frequency of payoff dominant equilibrium (part 1)

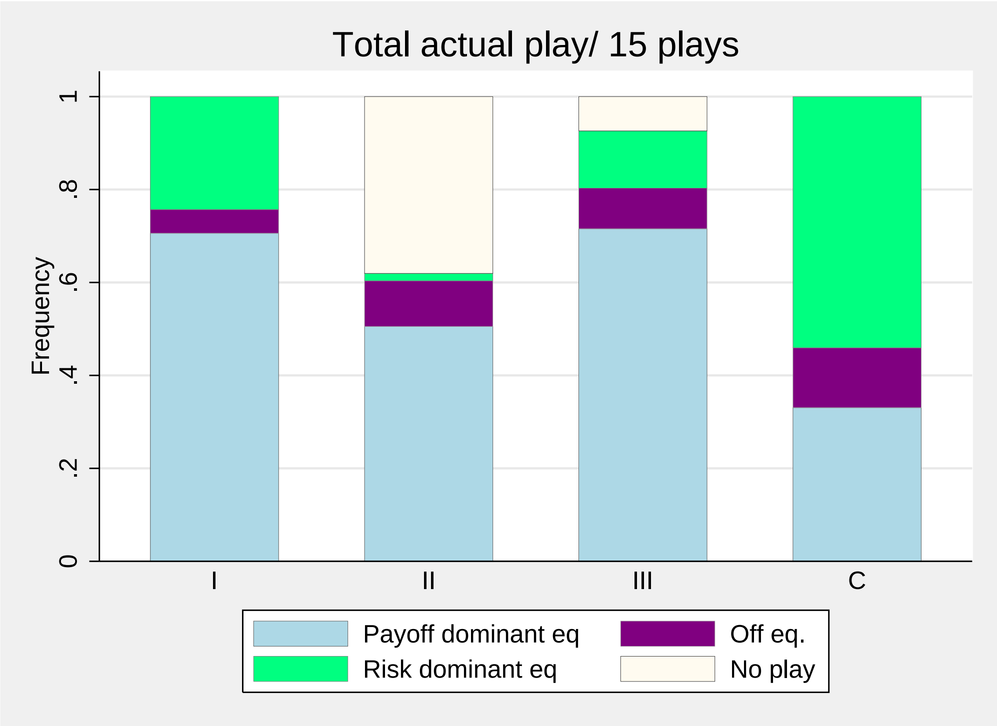


Dynamics of conditional frequency of payoff dominant equilibrium (part 2)



Results: (Out of) equilibrium play

Frequency of (out of) equilibrium play (part 1)



- Coordination failure and risk-dominant equilibrium play occurs most often in the baseline treatment (C).
- "No play" happens relatively often in treatment 1s_c (II) and also occurs in 2s_nc (III).
- In treatments with neighborhood choice the risk-dominant equilibrium is relatively infrequent.

Notes:

Part 1:

Statistical results of pair-wise comparsions of frequencies:

Surplus maximizing (blue) equilibrium:

	B	1s_nc	1s_c	2s_nc
B	-			
1s_nc	0.0287	-		
1s_c	?	?	-	
2s_nc	0.0287	?	0.0217	-

Note: MW U-tests, 1-sided; unit of observation: `frequency per group(?)`

Risk dominant (green) equilibrium:

	B	1s_nc	1s_c	2s_nc
B	-			
1s_nc	0.0961	-		
1s_c	0.0331	?	-	
2s_nc	0.0608	?	0.0873	-

Note: MW U-tests, 1-sided; unit of observation: `frequency per group(?)`

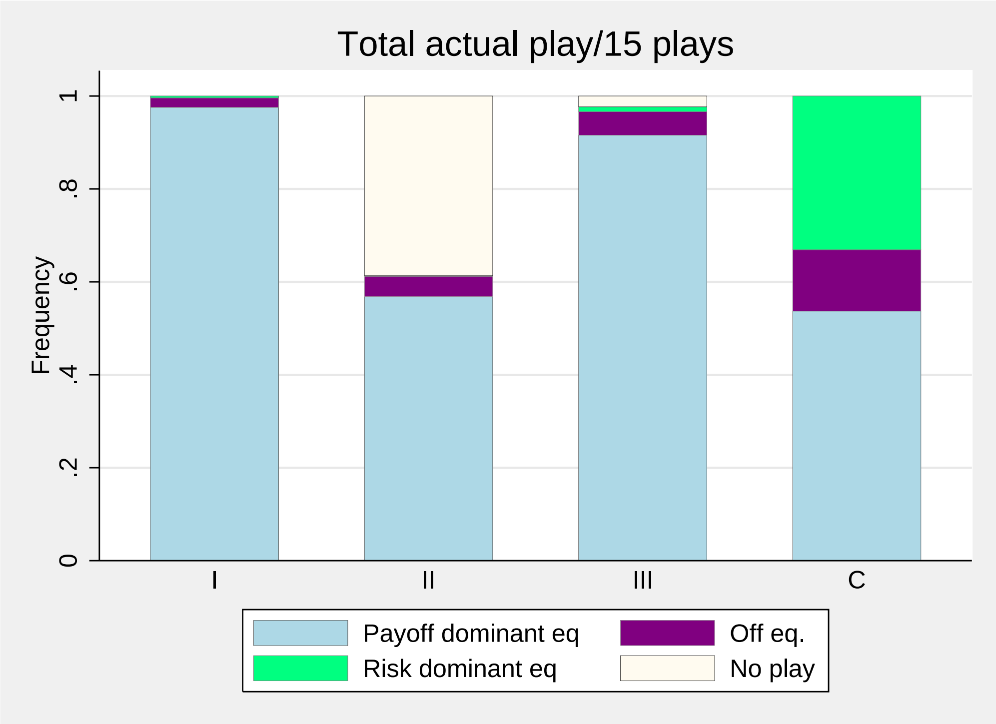
Off equilibrium (coordination failure):

	B	1s_nc	1s_c	2s_nc
B	-			
1s_nc	0.0121	-		
1s_c	?	0.0616	-	
2s_nc	?	0.0189	?	-

Note: MW U-tests, 1-sided; unit of observation: `frequency per group(?)`

Part 2:

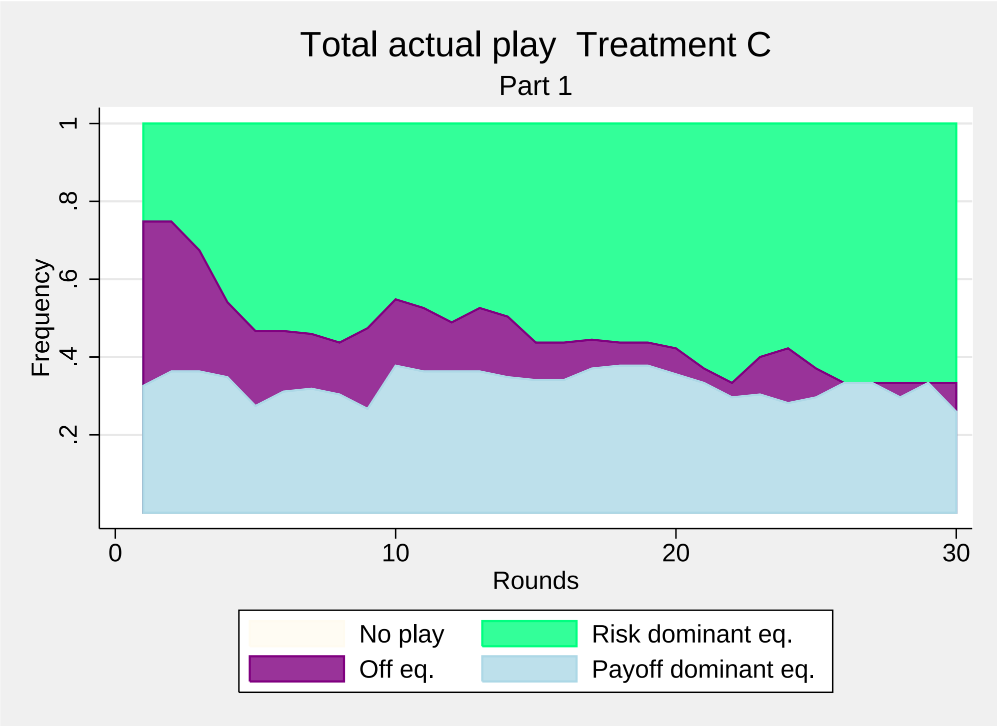
Frequency of (out of) equilibrium play (part 2)



Results: (Out of) equilibrium play

Dynamics of (out of) equilibrium play (part 1)

base



- In the baseline treatment (C) subjects learn to play an equilibrium.
- Learning dynamics are mainly towards the risk dominant equilibrium.

Notes:

Part 1:

Statistical results for correlation of frequencies with round:

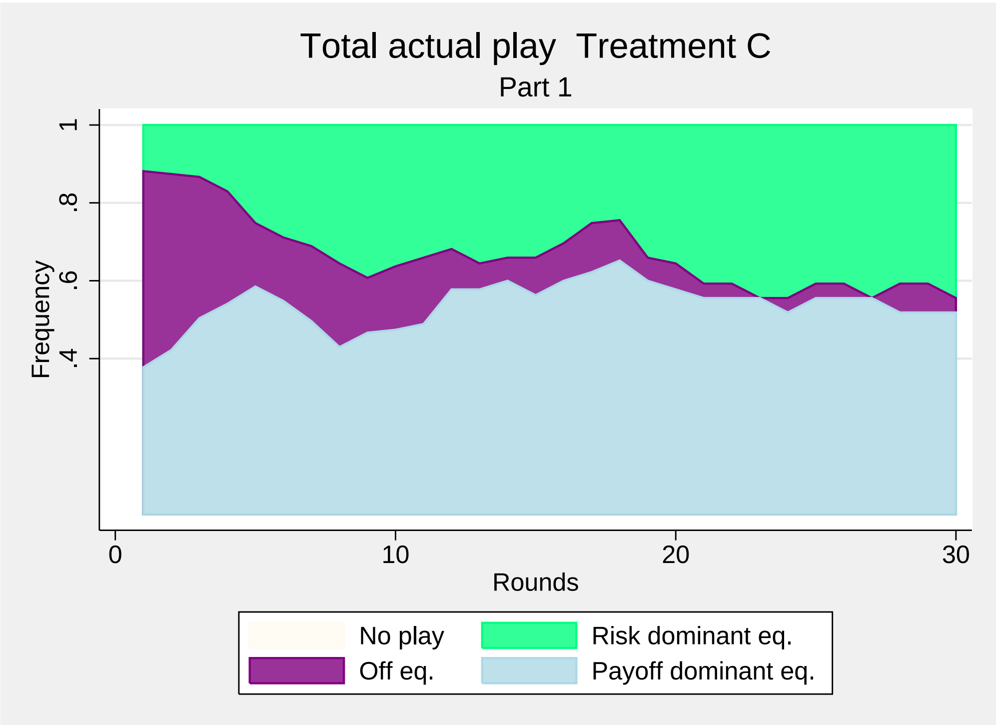
Treatment B:

	ρ	*p*
Off-equilibrium	-0.4015	0.0000
Surplus maximizing	?	?
Risk dominant	0.1746	0.0020

Note: Spearman rank order correlations, 1-sided; unit of observation: `frequency per round per treatmant(?)`

Part 2:

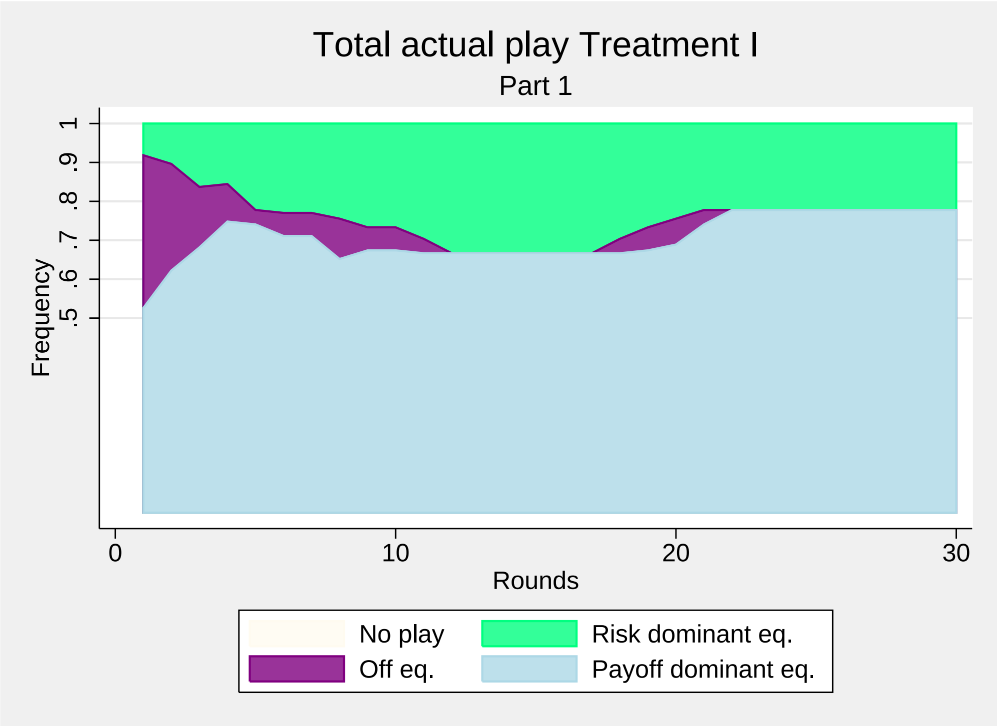
Dynamics of (out of) equilibrium play - base (part 2)



Results: (Out of) equilibrium play

Dynamics of (out of) equilibrium play (part 1)

1s_nc



- In treatment 1s_nc (I) subjects learn to play an equilibrium.
- Learning dynamics are towards both the risk dominant and the payoff dominant equilibrium.
- Subjects always play all possible games.

Notes:

Part 1:

Statistical results for correlation of frequencies with round:

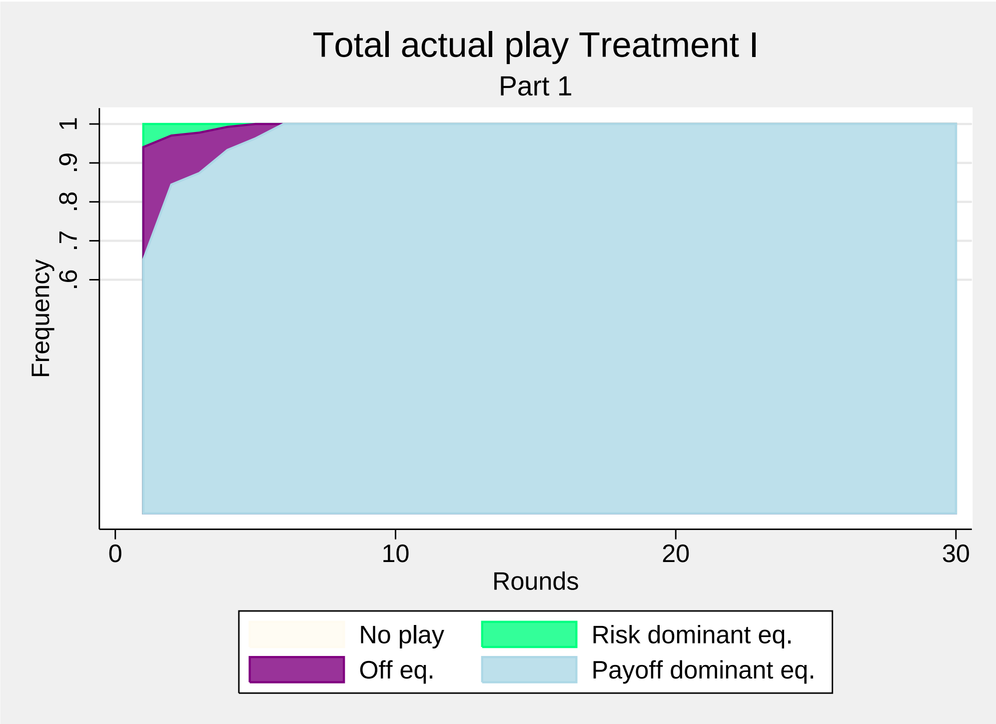
Treatment 1s_nc:

	ρ	*p*
Off-equilibrium	?	?
Surplus maximizing	0.1153	0.0293
Risk dominant	?	?

Note: Spearman rank order correlations, 1-sided; unit of observation: `frequency per round per treatmant(?)`

Part 2:

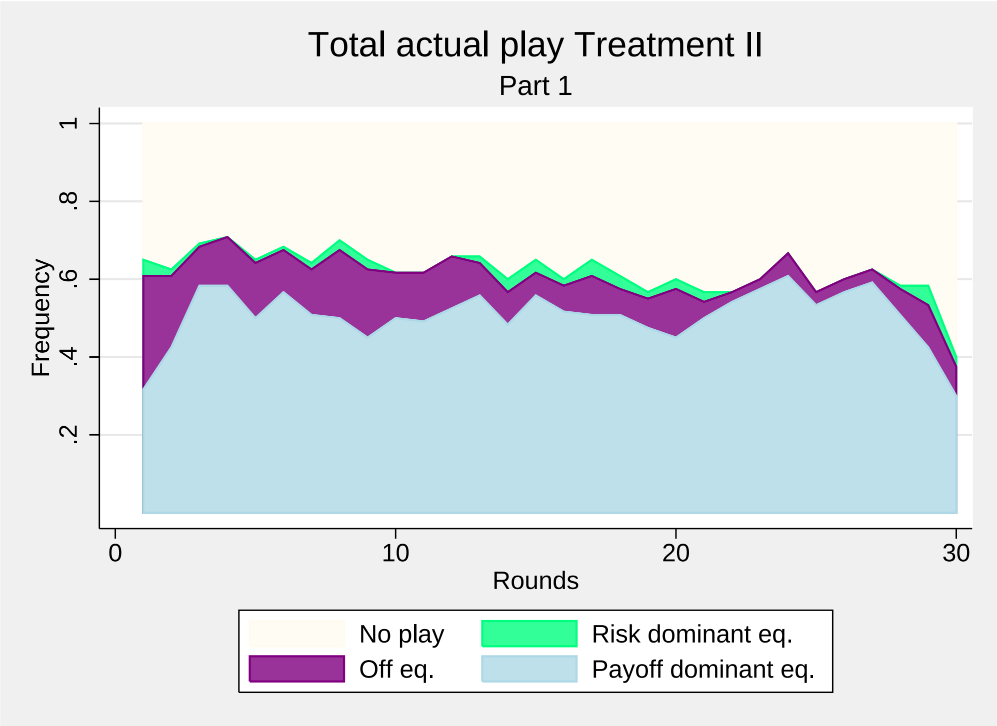
Dynamics of (out of) equilibrium play - 1s_nc (part 2)



Results: (Out of) equilibrium play

Dynamics of (out of) equilibrium play (part 1)

1s_c



- In treatment 1s_c (II) little learning dynamics towards more payoff dominant equilibrium play is observed.
- Subjects do not learn to play all possible games.

Notes:

Part 1:

Statistical results for correlation of frequencies with round:

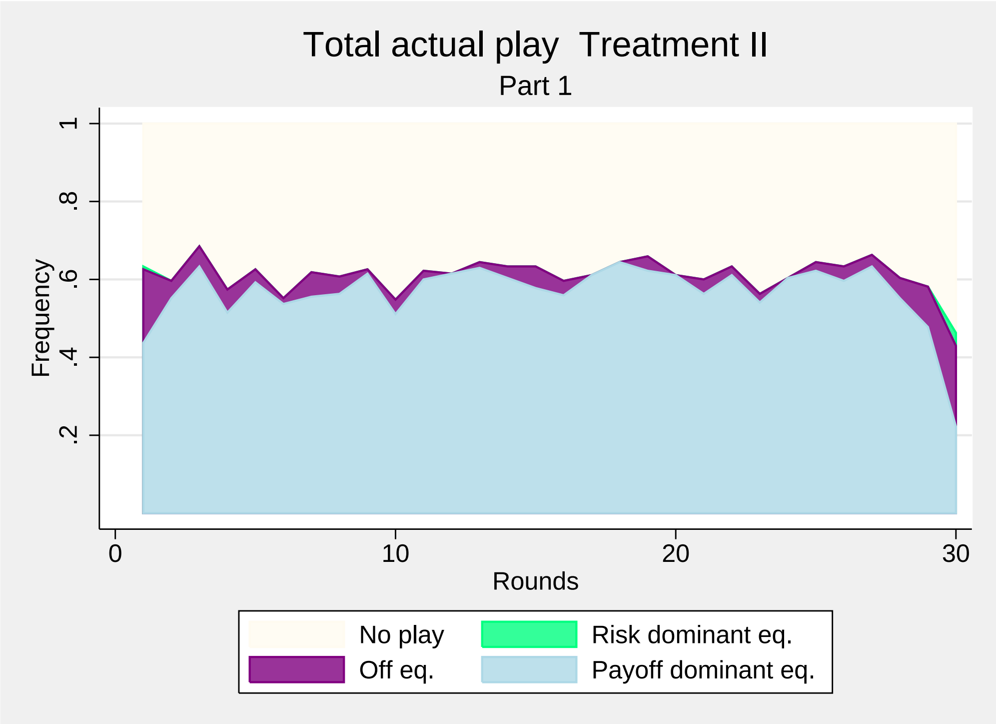
Treatment 1s_c:

	ρ	*p*
No play	0.2123	0.0005
Off-equilibrium	-0.3204	0.0000
Surplus maximizing	?	?
Risk dominant	?	?

Note: Spearman rank order correlations, 1-sided; unit of observation: `frequency per round per treatmant(?)`

Part 2:

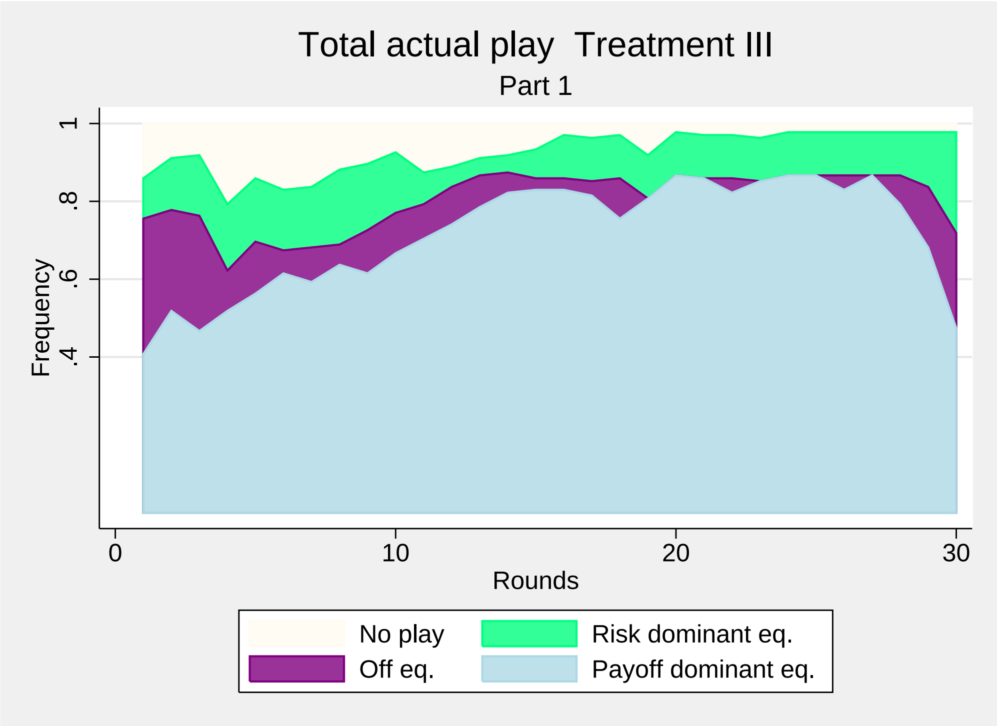
Dynamics of (out of) equilibrium play - 1s_c (part 2)



Results: (Out of) equilibrium play

Dynamics of (out of) equilibrium play (part 1)

2s_nc



- In treatment 2s_c (II) strong dynamics towards coordination on the payoff dominant equilibrium is observed (except for end-game effect).
- Subjects learn to play all possible games.

Notes:

Part 1:

Statistical results for correlation of frequencies with round:

Treatment 2s_nc:

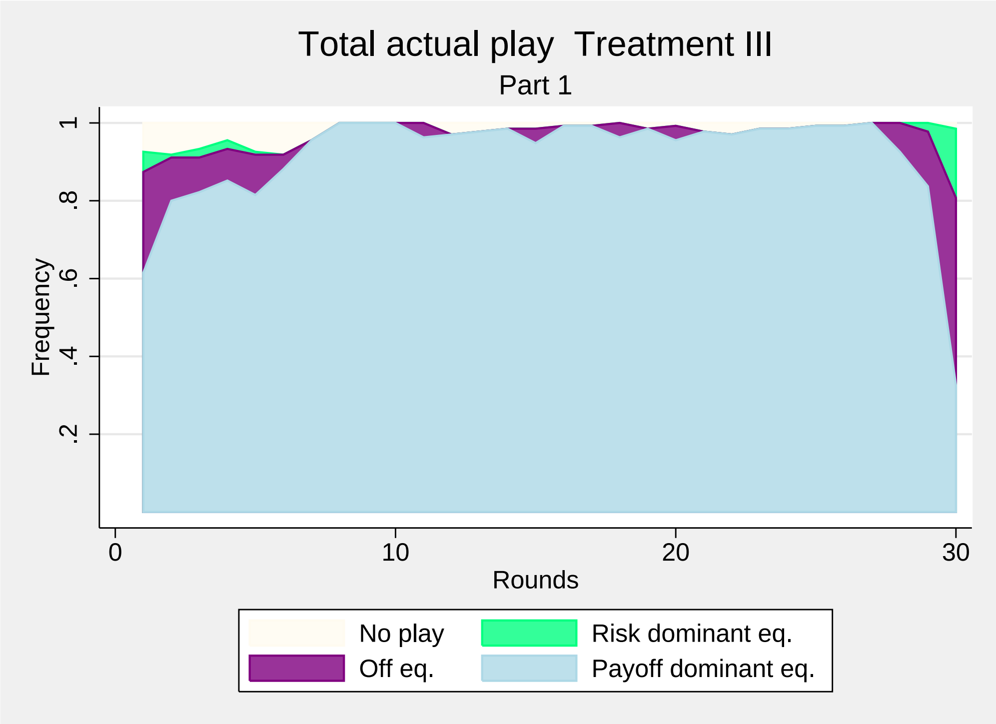
	ρ	*p*
No play	-0.3350	0.0000
Off-equilibrium	?	?
Surplus maximizing	?	?
Risk dominant	-0.1744	0.0021

Note: Spearman rank order correlations, 1-sided; unit of observation: `frequency per round per treatmant(?)`

```
!!!  check these correlations !!!
In the figure risk dominance does not seem to decrease!
```

Part 2:

Dynamics of (out of) equilibrium play - 2s_nc (part 2)



With whom to play?

Proposed interactions as a function of own action in t and others action in $t-1$

treatment 1s_nc (part 1)

i's action in period t	j's action in period $t-1$	
	payoff dominant	risk dominant
payoff dominant	99.98 [5544]	91.94 [186]
risk dominant	95.91 [171]	100.00 [1929]

- Overall link proposal behavior is almost independent of others most recent choice.
- Subjects playing payoff dominant, least often propose links to subjects that played risk dominant

Notes:

Proposed interactions as a function of own action in t and others action in $t-1$
treatment 1s_nc (part 2)

i's action in period t	j's action in period $t-1$	
	payoff dominant	risk dominant
payoff dominant	99.86 [7680]	85.55 [90]
risk dominant	94.29 [35]	100.00 [25]

With whom to play?

Proposed interactions as a function of own action in t and others action in $t-1$

treatment 1s_c (part 1)

i's action in period t	j's action in period $t-1$	
	payoff dominant	risk dominant
payoff dominant	40.81 [5435]	5.11 [665]
risk dominant	39.07 [645]	25.58 [215]

- Frequency of proposed links is relatively low, indicating a coordination problem in link formation.
- Subjects who play payoff dominant in t rarely propose to play with a subject that played risk dominant in $t-1$.

Notes:

Proposed interactions as a function of own action in t
and others action in $t-1$
treatment 1s_c (part 2)

i's action in period t	j's action in period $t-1$	
	payoff dominant	risk dominant
payoff dominant	35.79 [6497]	4.23 [213]
risk dominant	41.60 [238]	33.33 [12]

With whom to play?

Proposed interactions as a function of own action in t and others action in $t-1$

treatment 2s_nc (part 1)

i's action in period t	j's action in period $t-1$	
	payoff dominant	risk dominant
payoff dominant	98.52 [5927]	58.72 [453]
risk dominant	95.25 [463]	98.58 [987]

- Subjects who play payoff dominant in t frequently choose the **dominated action** of refusing to interact with a subject that played risk dominant in $t-1$. Strongly suggests existence of *efficiency enforcement* through exclusion.
- All other cases, frequency of proposed links is very high.

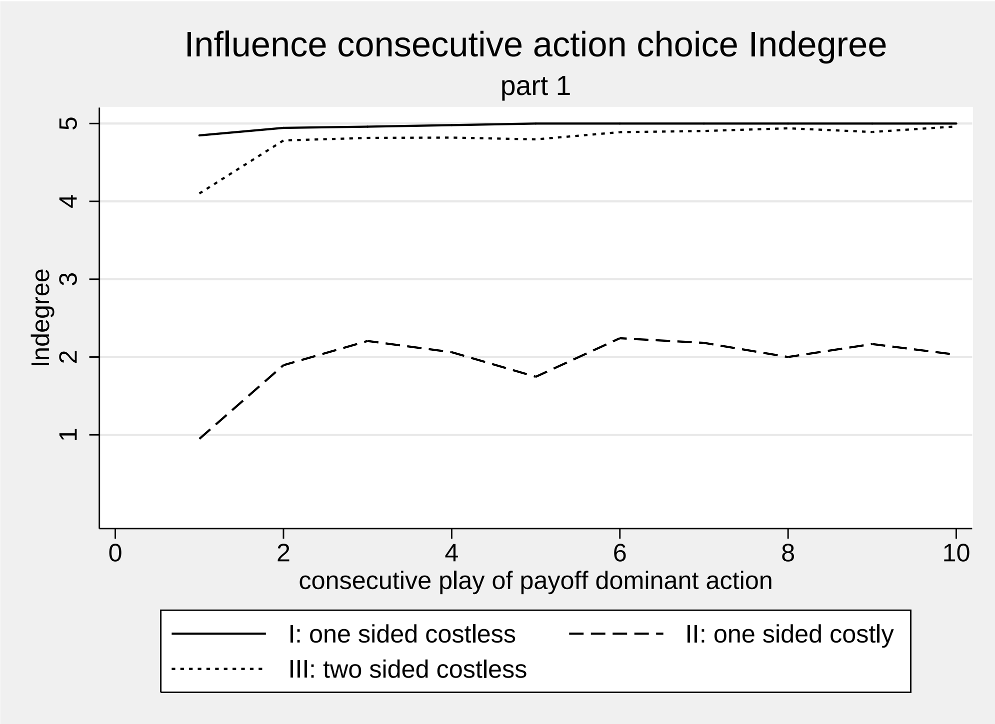
Notes:

Proposed interactions as a function of own action in t
and others action in $t-1$
treatment 2s_nc (part 2)

i's action in period t	j's action in period $t-1$	
	payoff dominant	risk dominant
payoff dominant	99.41 [7428]	71.43 [147]
risk dominant	99.06 [212]	100.00 [43]

Results: Indegree & action choice

Indegree as a function of consecutive choice of the payoff dominant action

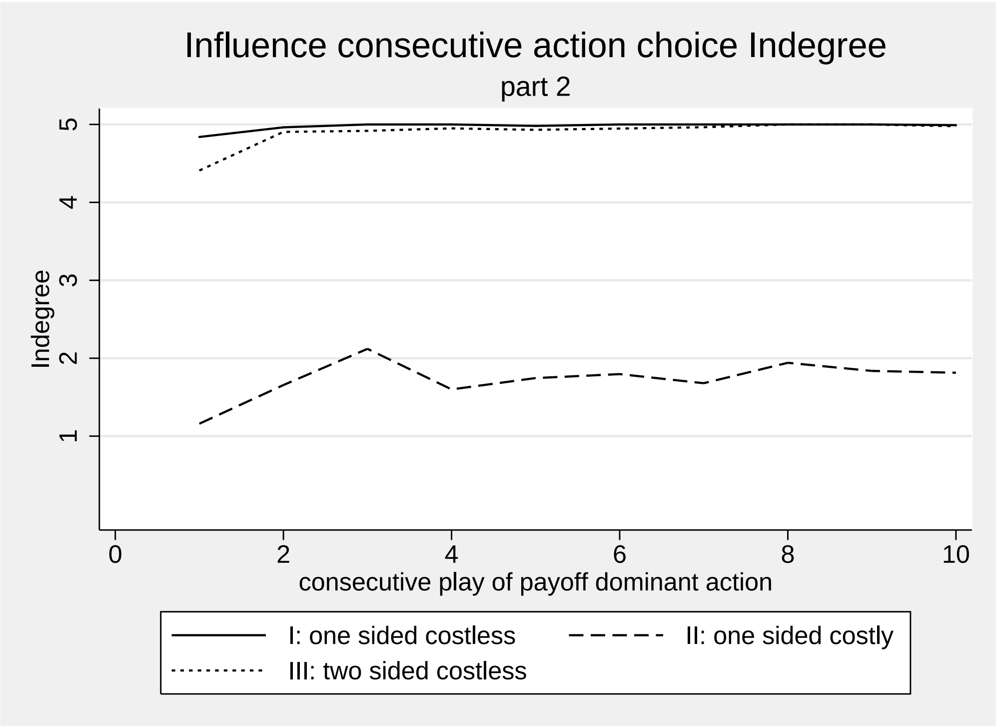


Inclusion:

- With and without linking costs indegree is increasing and converges to optimum.

Notes:

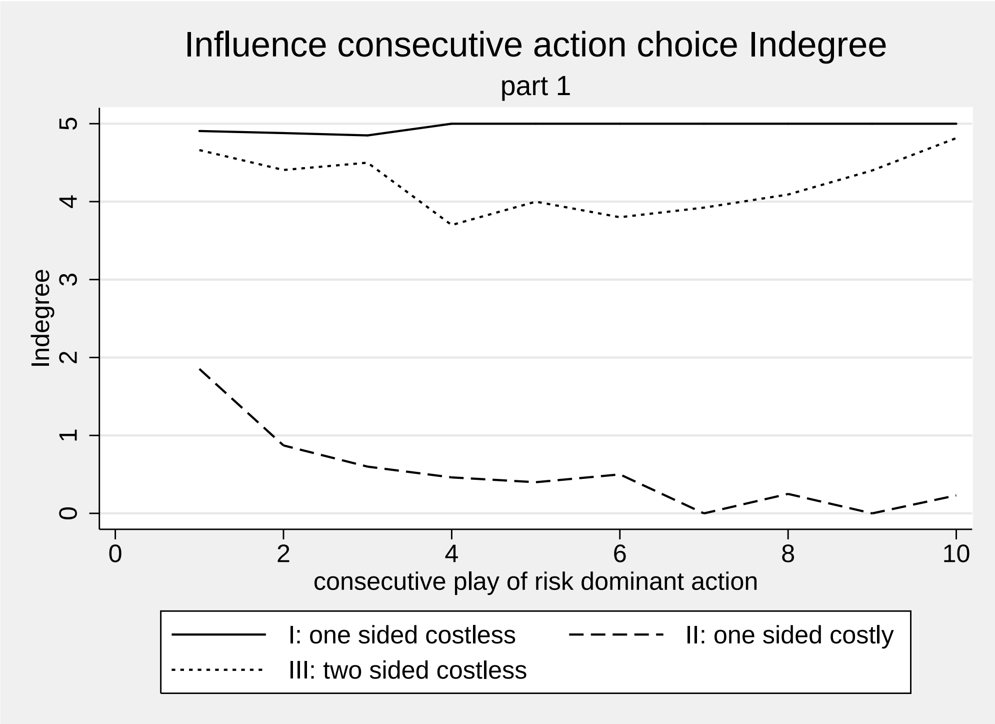
Indegree as function of consecutive choice of payoff dominant action



Results: Indegree & action choice

Indegree as a function of consecutive choice

of the risk dominant action

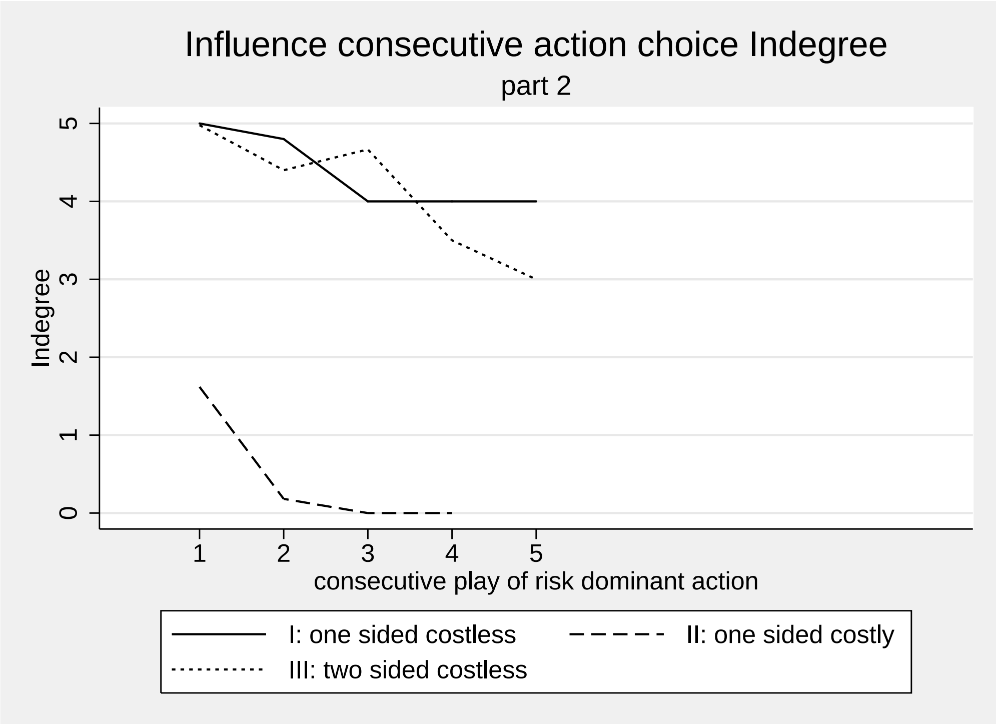


Exclusion:

- In 1s_nc indegree is at maximum level.
- In 2s_nc indegree firstly decreases but increases again to reach the maximum level.
- In 1s_c indegree strongly decreases and converges to zero.

Notes:

Indegree as function of consecutive choice of payoff dominant action



Summary & Conclusion

- Without free neighborhood choice coordination failure prevails.
- Free neighborhood choice eliminates coordination failure almost completely.
- When mutual consent is required efficiency is enforced by exclusion
  $\rightarrow$ in contrast to theoretical prediction (see also Ule (2005), Riedl & Ule (2002, 2008) on cooperation)
- With unilateral and costly linking coordination failure on network formation
  $\rightarrow$ ignored by theoretical models (see also Falk & Kosfeld (2003), Goeree, Riedl, & Ule (2007) on network formation)

Summary & Conclusion

- Surprisingly, even with unilateral and costless linking coordination failure vanishes
  $\rightarrow$ in contrast to theoretical prediction and behavioral expectations (‘puzzle’?).
- Need theoretical models that can accommodate all regularities simultaneously.