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Institution Formation in Weakest-Link Games with Fixed Neighborhoods

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In a nutshell

Main contribution: Test the capacity of endogenous institutions enabling binding commitments to solve the coordination problem in weakest link games (conventional and riskier environments).

Methods: Non-cooperative and cooperative game theory with fully rational players and standard preferences, laboratory experiment, novel additional theory (risk dominance, trembling hand, QRE, (A)QRE).

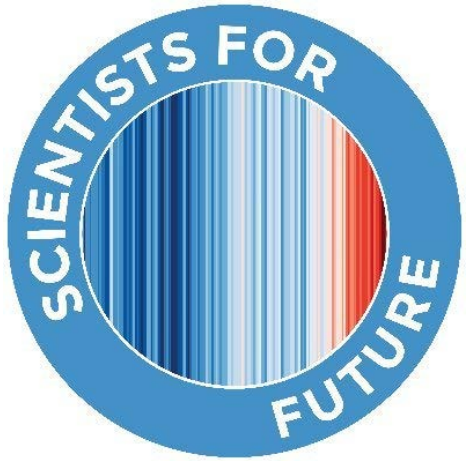
Main results:

Endogenous institution formation alleviates the coordination problem…

… but it does not trivially solve it.

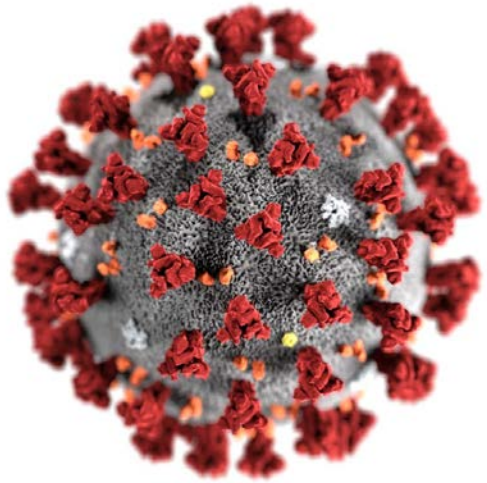
Motivation

Provision of public goods can be conceived from different angles:



Summation technology: sum of individual contributions matters

Best-shot: maximum of all individual provision levels matters



Weakest-link: smallest individual provision level matters

Other examples: Biodiversity, network integrity, "Anarchia island"

Motivation

Long tradition to study the determinants of success in weakest-link:

Theoretically (e.g. Hirschleifer 1983, Sandler and Arce 2002, Cornes 1993, Cornes and Hartley 2007, Vicary 1990, Holzinger 2001...)

Experimentally (e.g. Van Huick et al 1990; Cooper et al 1990; Cachon and Camerer 1996; Feri et al 2010).

Experimental evidence addresses fostering coordination and enhancing efficiency:

Coercive policies, costly policies, communication, imposing costs to enter the game, etc.

In this study, we address the **endogenous formation of institutions** (entailing binding contributions) as an alternative intervention:

Higher social acceptance (voluntary), easier political implementation (non-coercive), and cheap (for members and for policy-makers).

Weakest institution that theoretically can support full efficiency (novel theory).

Related Literature

Theory

Weakest-link (Hirschleifer 1983, Sandler and Arce 2002, Cornes 1993, Cornes and Hartley 2007, Vicary 1990, Holzinger 2001...)

Coalition formation and weakest-link games with **asymmetric** players (Caparrós and Finus 2020).

Coalition formation and **summation** technology (dëAspremont et al. 1983, Barrett 1994)

► Lack of refinements for the selection among multiple equilibria with coalition formation in the weakest-link game with conventional symmetric players.

Related Literature

Experiments

Determinants of success in weakest-link (Van Huick et al 1990; Cooper et al 1990; Cachon and Camerer 1996; Feri et al 2010)

Coercive policies: weakest-link excluding neighbors (Croson et al 2015; Riedl et al 2016).

Costly policies: weakest-link with financial incentives (Brandts and Cooper 2006; Hamman et al 2007) or reducing effort costs (Goeree and Holt 2005; Brandts et al 2007).

Communication in the weakest-link (Van Huyck et al. 1993; Devetag 2005; Blume and Ortmann 2007; Chauduhri et al 2009; Kriss et al. 2016; Fehr 2017; Avoyan and Ramos 2023).

Others: imposing costs to enter the game (Cachon and Camerer 1996), time pressure in decision-making (Feri et al 2010).

- Theoretical results with multiple equilibria (whenever there is theory).

Endogenous institutions: coalition formation only previously explored with **summation technology** (Kosfeld et al. 2009, McEvoy 2012)

Contribution

Provide novel experimental and theoretical results on the capacity of endogenous institutions to enhance efficiency in weakest-link environments (with fixed members).

Research Questions:

1: Will voluntary institutions be formed? If so, of which size?

2: Will the capacity to form institutions enhance efficiency (higher minimum and average numbers)?

Decision Setting

2 weakest-link games:

Smallest number chosen by any participant in your group (including yourself)

Number you choose	7	6	5	4	3	2	1
7	130	110	90	70	50	30	10
6		120	100	80	60	40	20
5			110	90	70	50	30
4				100	80	60	40
3					90	70	50
2						80	60
1							70

Source: Van Huick et al (1990), all entries multiplied by 100.

Smallest number chosen by any participant in your group (including yourself)

Number you choose	7	6	5	4	3	2	1
7	130	0	0	0	0	0	0
6		120	0	0	0	0	0
5			110	0	0	0	0
4				100	0	0	0
3					90	0	0
2						80	0
1							70

Source: Feri et al (2010).

- 7 Pareto ranked equilibria (those on the diagonal)
- Pareto dominance: all choose 7.
- Potential function (risk dominance): all choose 1.

Decision Setting: Institution

Stage 1: Membership

- All players simultaneously choose a membership strategy “inn” or “out”
- Players who announce “out” act as singletons
- Players who announce “inn” become candidate members

Stage 2: Confirmation

- Candidate members are informed of the number of candidate members
- Candidate members decide on confirming membership (institution forms if all confirm)

Stage 3: Provision

- Non-members: Choose number independently
- Members: All members propose a number; minimum of members is implemented by the institution

Decision Setting: Institution

Attributes:

Unanimity for membership and the choice of the number within the institution:

Render it attractive to join the institution (no fear of being overruled by others)

Members must fear that any provision level above 1 may not be matched by outsiders

As long as membership ≥ 2, the risk for the members is lower than without the institution

Same for outsiders to the institution.

Equilibria:

All numbers between 1 and 7 are Nash equilibria in stage 3 (even with complete membership)

Multiple subgame perfect equilibria exist for membership choices

Pareto-dominance does not select a unique equilibrium in the game with institution formation

Predictions

Hypothesis 1: Subjects will use the opportunity to establish Institutions.

Hypothesis 2: The minimum and average numbers in treatments with Institutions will be higher than those of treatments without institution formation.

Experimental Design

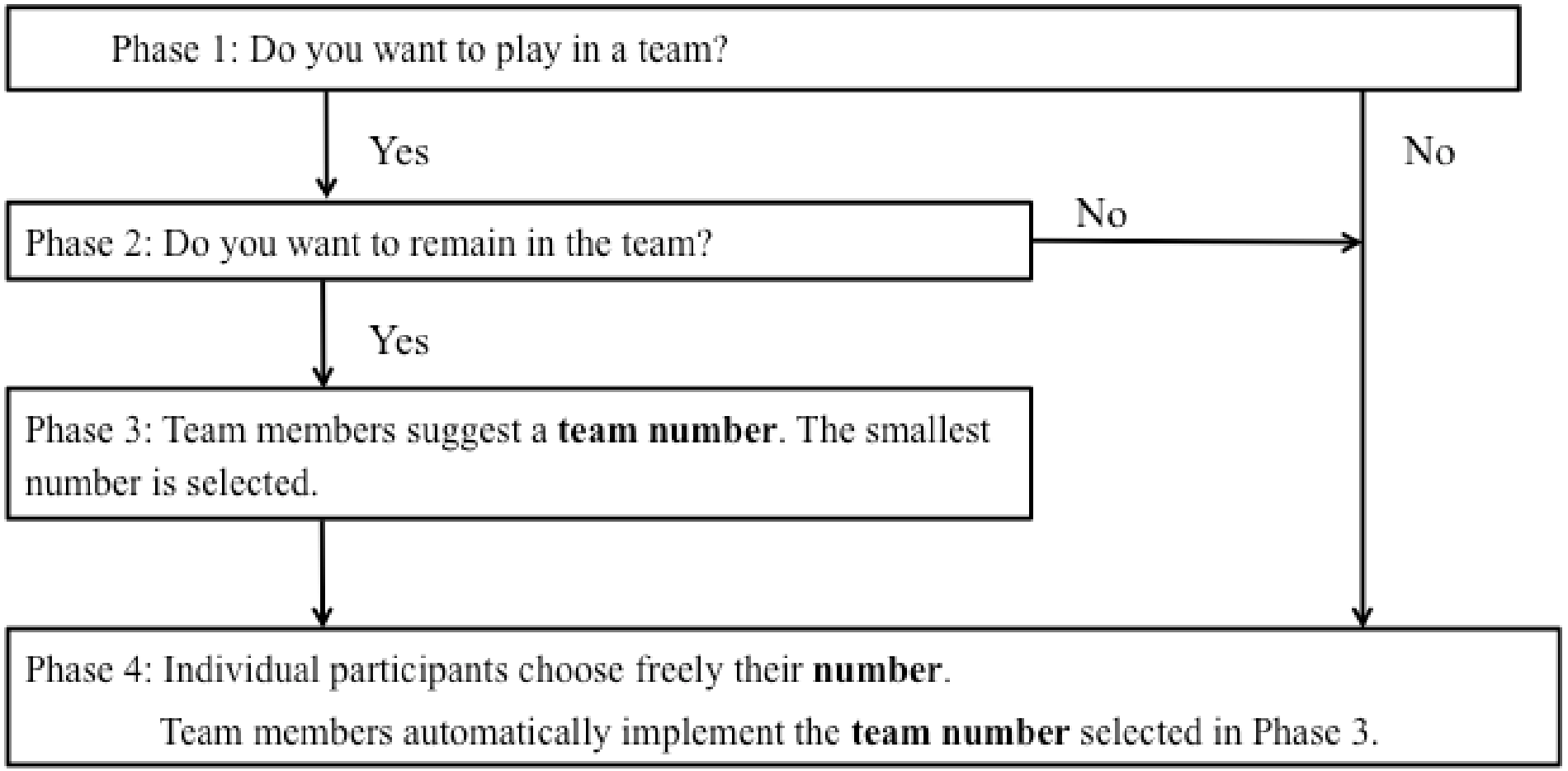
2 Repeated weakest-link games with groups of 8 in partner matching

Between-subjects design, 2 treatment conditions with/without voluntary institution (n= 272 subjects)

10 round of baseline game, followed by 10 rounds varying for treatments (2x2):

Treatment	Payoff Function	Institution, Part 1 (Round 1-10)	Institution Part 2 (Round 11-20)
Baseline	Van Huick et al. (1990)	No	No
Baseline-Institution	Van Huick et al. (1990)	No	Yes
Risk	Feri et al. (2010)	No	No
Risk-Institution	Feri et al. (2010)	No	Yes

Experimental Design



Results – Institution formation

Initiated and confirmed institutions across the treatment "Baseline-Institution"

	Initiated institutions	Confirmed institutions	Confirmation rate (%)	Percentage of confirmed institutions by size
Total	90	80	88.89	100
Two Members	1	1	100	1.25
Three Members	8	8	100	10
Four Members	3	2	66.67	2.5
Five Members	5	4	80	5
Six Members	17	14	82.35	17.5
Seven Members	12	10	83.33	12.5
Eight Members	44	41	93.18	51.25

Initiated and confirmed institutions across the treatment "Risk-Institution"

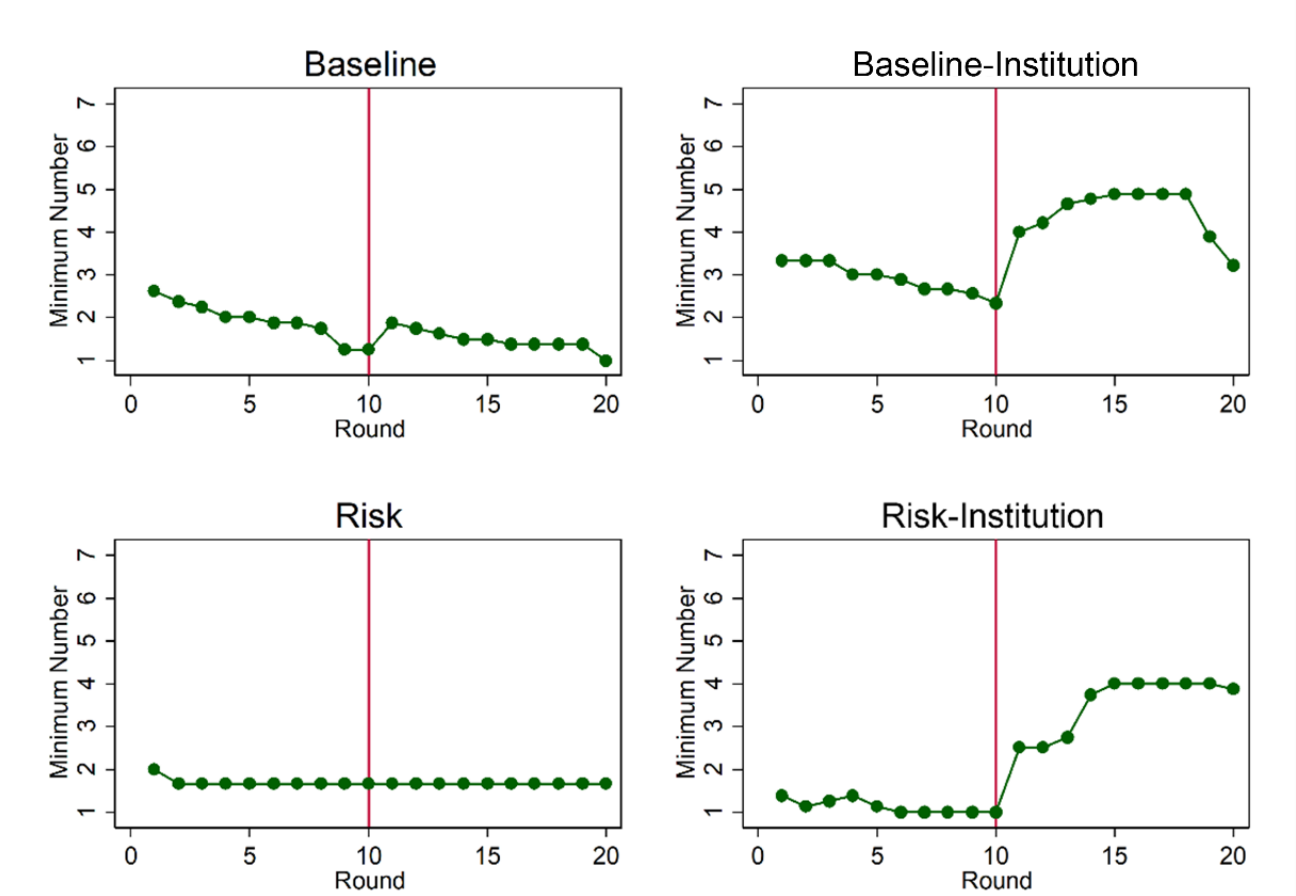
	Initiated institutions	Confirmed institutions	Confirmation rate (%)	Percentage of confirmed institutions by size
Total	78	48	61.54	100
Two Members	3	0	0	0
Three Members	2	0	0	0
Four Members	2	0	0	0
Five Members	8	1	12.5	2.08
Six Members	6	0	0	0
Seven Members	11	2	18.18	4.17
Eight Members	46	45	97.83	93.75

Institutions are initiated every possible time in Baseline-Institution (90/90) and almost every time in Risk-Institution (78/80).

The majority of the institutions are confirmed in Baseline-Institution, but almost exclusively the full-membership is confirmed in Risk-Institution (93.75%).

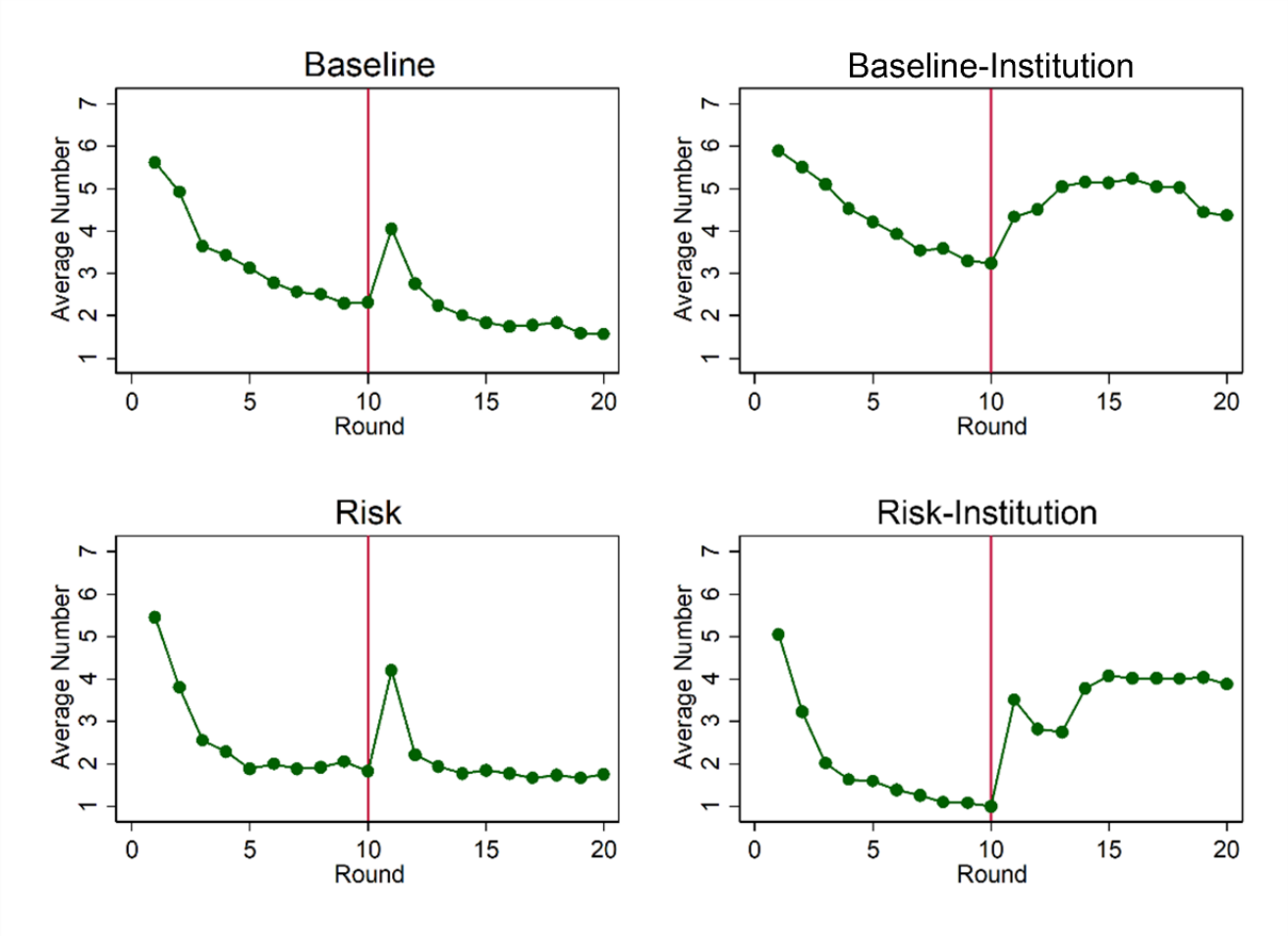
Result 1: Individuals use the opportunity to form institutions: Institutions are initiated and confirmed.

Results – Minimum Numbers



Result 2: Minimum numbers and average numbers are higher when institution formation is possible. Overall, provision levels do not reach the Pareto-optimal value.

Results – Average Numbers



Result 2: Minimum numbers and average numbers are higher when institution formation is possible. Overall, provision levels do not reach the Pareto-optimal value.

Results – Dynamics

Average numbers: Institution formation breaks the trend of declining average numbers throughout periods (Jonckheere-Terpstra test, confirmed by Friedman test):

Significant declining trend in Part 1 in all cases,

Only without institution formation in Part 2

Minimum numbers: Institution formation stabilizes minimum numbers (Baseline-Institution) and stimulates an increasing trend of minimum numbers in risky environments (Risk-Institution) (idem analyses):

Significant declining trend in Part 1 in all cases except in Risk (always aprox. 1).

In Part 2, decrease for Baseline; no trend for Baseline-Institution and Risk; increase for Institution-Risk.

Result 3: Institution formation stops the downward trend of average and minimum numbers over rounds.

Theory (2)

Risk dominance

VVHB (FIS): Play 1 Institution: Full membership, play 7

Trembling hand

VVHB (FIS): Any number Institution: Full membership, play 7

Proper equilibria

VVHB (FIS): Any number Institution: Full membership, play 7

QRE/AQRE

VVHB (FIS): Play 1 Institution: Full membership, play 7

Results – Estimation of the (A)QRE

Table 7: Observed and estimation-based predicted average and minimum numbers for rounds 16 to 20

	Observed Data		(A)QRE predictions[(1)]	
	Average Number	**Minimum Number**	**Average Number**	**Minimum Number**
Baseline	1.7063	1.3000	1.7069 [1.3523-2.6241]	1.0009 [1.0000-1.0380]
Risk	1.7167	1.6667	1.4565 [1.0907-2.6029]	1.0000 [1.0000-1.0025]
Baseline-Institution	4.8222	4.3556	2.5435 [1.8667-3.6699]	1.0314 [1.0029-1.2487]
Risk-Institution	3.9906	3.9750	1.2735 [1.0142-4.0000]	1.0000 [1.0000-1.3417]

[(1)] (A)QRE predictions use the $\hat{\lambda}$ shown in Table 6. 95% confidence intervals are shown in square brackets. Average and minimum numbers for a given treatment are the arithmetic means over all groups and all five rounds.

Result 4: Observed average numbers are within the confidence intervals predicted by the (A)QRE for the treatments Baseline, Risk and Risk-Institution, and above for Baseline-Institution. Observed minimum numbers are above the confidence intervals in all treatments.

Conclusion

Nash equilibrium

- NE with self-interested payoff-maximizing preferences has limited predictive power at the provision or membership stage

Risk dominance, trembling hand, proper equilibria and (A)QRE (for high lambda) predict full membership and full efficiency with institutions

A(QRE) estimations:

- Within confidence interval or more pessimistic (better at the provision stage, weakest-link)

Empirical results

- Coordination failure in weakest-link game is confirmed
- Coalitions foster efficiency, but do not solve the problem trivially

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Results – Estimation of the (A)QRE

Table 6: Estimation results for the logit QRE and AQRE models for rounds 16-20

	No institution treatments (QRE)		Institution treatments (AQRE)	
	Baseline	**Risk**	**Baseline-Institution**	**Risk-Institution**
Full sample				
$\hat{\lambda}$	0.0870***	0.0527***	0.0435**	0.0627*
	(0.0242)	(0.0126)	(0.0173)	(0.0338)
Log-L	369.6219	223.6916	737.2310	360.4983
M	320	360	360	320

Note: Standard errors are shown in parentheses; $\hat{\lambda}$: estimated λ; M: number of observations. Significance at the 10% (*), 5% (**) and 1% (***) level.