Voting on contributions to a threshold public goods game – an experimental investigation

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INSTITUTE OF ECONOMICS

Background

International negotiations to prevent climate change

- 2°C-target (2009 Copenhagen Accord) as an upper limit of acceptable global warming
- 2°C-target corresponds to a specific concentration of greenhouse gases in the atmosphere (**threshold value**)*
- Necessary reduction of GHGs can only be reached if many countries contribute (**public good**)

- The situation is a **threshold public-goods game:**
  - Incentive to free-ride, but no dominant strategy
  - Coordination (on threshold) more important than cooperation (high contributions)

*E.g. about 350 ppm for CO2 (Hansen et al. 2008).

Basic model of a threshold PG game*

Parameters

- n number of players
- e endowment
- q_i player i's contribution to the PG, with $q_i \in [0, \bar{q}]$
- c_i player i's marginal costs of contribution
- Q total contribution of all players, i.e., $Q = \sum_i q_i$
- $\bar{Q}$ randomly distributed contribution threshold
- x penalty, if threshold is missed, i.e., $Q < \bar{Q}$ (no refund!)

Payoff function

- $\pi_i = \begin{cases} e - c_i q_i & Q \geq \bar{Q} \\ e - c_i q_i - x & Q < \bar{Q} \end{cases}$ player i's individual payoff

*Cf. Suleiman / Budescu / Rapoport (2001): Provision of Step-Level Public Goods with Uncertain Provision Threshold and Continuous Contribution. Group Decision and Negotiation, Vol. 10, p.253-74.

Experimental Design I

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Parameter choice for the basic model (all treatments)

- 5 players
- Individual contributions q_i up to 10.00 CU (2 decimals)
- Total contribution Q up to 50 CU
- (Discrete) **uniform distribution of threshold value** $\bar{Q}$ over:

$$\{16 \text{ CU}, 17 \text{ CU}, 18 \text{ CU}, 19 \text{ CU}, 20 \text{ CU}, 21 \text{ CU}, 22 \text{ CU}, 23 \text{ CU}, 24 \text{ CU}\}$$

- Player i‘s payoff (in ExCU, 1 ExCU = €0.50):

$$\pi_i = \begin{cases} 25 - c_i q_i & Q \geq \bar{Q} \\ 15 - c_i q_i & Q < \bar{Q} \end{cases} \qquad (x = 10 \text{ ExCU})$$

If $c_i \leq \frac{50}{24} \frac{\text{ExCU}}{\text{CU}} \approx 2.08 \frac{\text{ExCU}}{\text{CU}}$ then $Q = 24 \text{ CU}$ is the **“ex ante” social optimum.**

Experimental Design II

Marginal costs of contribution

- Homogeneous: $c_H = c_L = 1 \frac{\text{ExCU}}{\text{CU}} \text{ (5x)}$
- Heterogeneous: $c_H = 1.25 \frac{\text{ExCU}}{\text{CU}} \text{ (3x)}$ $c_L = 0.77 \frac{\text{ExCU}}{\text{CU}} \text{ (2x)}$
- Both designs allow the same **payoff-symmetrical allocation** of each possible threshold value with (at most) **one decimal place**:

Total contribution	Individual payoff (threshold reached)	Individual payoff (threshold not reached)
24 CU	20.2 ExCU	n. a.
23 CU	20.4 ExCU	10.4 ExCU
22 CU	20.6 ExCU	10.6 ExCU
…	…	…
16 CU	21.8 ExCU	11.8 ExCU

Experimental Design III

Different methods of coordination

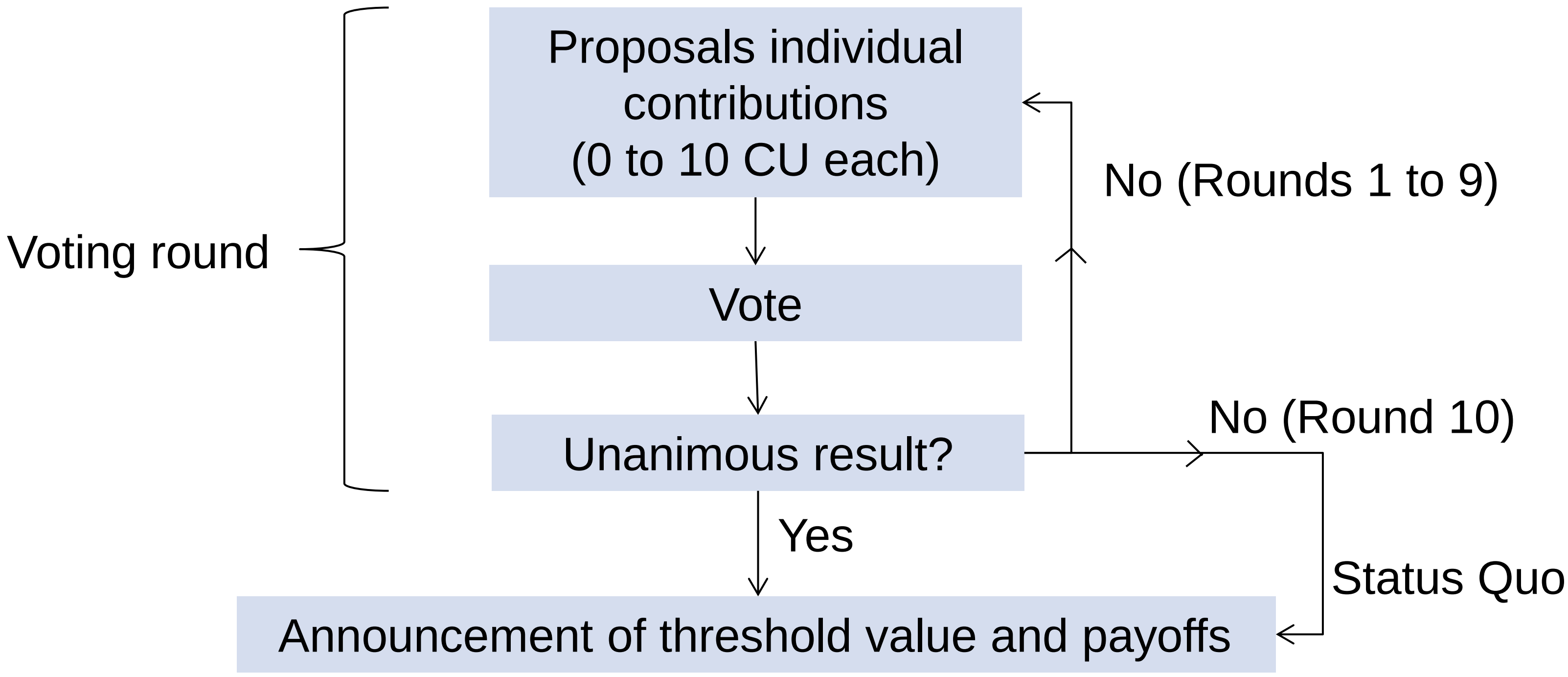
- **Repeated game**: Q-Q-Q-Q-Q-Q-Q-Q-Q-Q
  - Repeated voluntary contributions followed by threshold events (Q)
  - Partner design
  - 10 rounds, only 1 random round paid
  - Public information: Contributions and threshold values of earlier rounds

- **Bottom-up vote**: V-(V-V-V-V-V-V-V-V-V)-Q
  - (repeated) **binding unanimous vote** on individual contributions (V)
  - **Only one** threshold event (Q)
  - **“Status Quo”** if no agreement after 10 rounds:

    $$Q = 0 \text{ CU}, \forall\, i: \; q_i = 0 \text{ CU}$$

  - Non-cooperative voting mechanism (no communication)
  - Public information: Proposals and votes of earlier rounds

Course of the bottom-up voting treatments



Selection of outcomes in threshold PG games

Coordination problem

- Many possible allocations of socially optimal total contribution (24 CU)
- Large number of socially optimal outcomes makes coordination difficult

Selection criteria

- Payoff-symmetrical outcome with highest welfare (PS)
- Welfare-maximizing outcome (WM)
- Contribution-symmetrical outcome with highest welfare (CS)

Theoretical solutions after selection

- Homogeneous costs: WM = PS = CS
- Heterogeneous costs: WM ≠ PS ≠ CS

Perfect Bayesian Nash equilibria

- Voting treatments:
  - Determine socially optimal total contribution (here: Q* = 24 CU)
  - Reference with individual outcome for status quo (here: π_i = 15 ExCU)
  - Equilibrium outcomes are all allocations of Q* which for each player yield at least as much payoff as SQ:
    - Hom: All allocations of Q*
    - Het: All allocations of Q* in which $q_H \leq 8$ CU
- Repeated game:
  - SQ is inferior equilibrium outcome
  - Contributing Q* is individually optimal, if an increase of contributions by 1 CU increases individual payoff by more than the additional contribution costs, i.e., if $c \leq \frac{x}{Q_{max} - Q_{min} + 1}$
    - Hom (c = 1): True, since $c \leq 10/9$
    - Het ($c_L = 0.77$, $c_H = 1.25$): False, since $c_H > 10/9$.
- **PS, WM, and CS are Nash eq. in all treatments but NVHet.**

Experimental Design IV

Overview of treatments and hypotheses

N = 8	Homogeneous costs	Heterogeneous costs
Unanimous vote	WM/PS/CS: $q = 4.8$ CU	WM: $q_L = 10$ CU $q_H = 1.34$ CU PS: $q_L = 6.24$ CU $q_H = 3.84$ CU CS: $q_L = q_H = 4.8$ CU
Repeated game (each round)	WM/PS/CS: $q = 4.8$ CU	WM*: $q_L = 10$ CU $q_H = 1.34$ CU PS*: $q_L = 6.24$ CU $q_H = 3.84$ CU CS*: $q_L = q_H = 4.8$ CU

- Expected total contributions: Q = 24 CU in all cases.

*These outcomes are not individually optimally for high-cost players!

Results from the literature I

Social dilemma with vote on contributions (no threshold)

- Similarities of earlier studies:
  - Repeated games (multiple contribution rounds in sequence, each with separate vote)
  - No agreement → game without vote (operational game)

- Results:
  - **Unanimous vote** achieves efficient outcomes, but is **only 60% successful** (Walker, Gardner, Herr, Ostrom 2000)
  - **Heterogeneity makes agreement more difficult** in a majority vote (Margreiter, Sutter, Dittrich 2005)
  - Binding majority vote results in higher contributions than non-binding rule (Kroll, Cherry, Shogren 2007)

Results from the literature II

Public good with threshold (no vote)

- Total contributions oscillate around (certain) threshold value (e.g., Croson & Marks 2000).

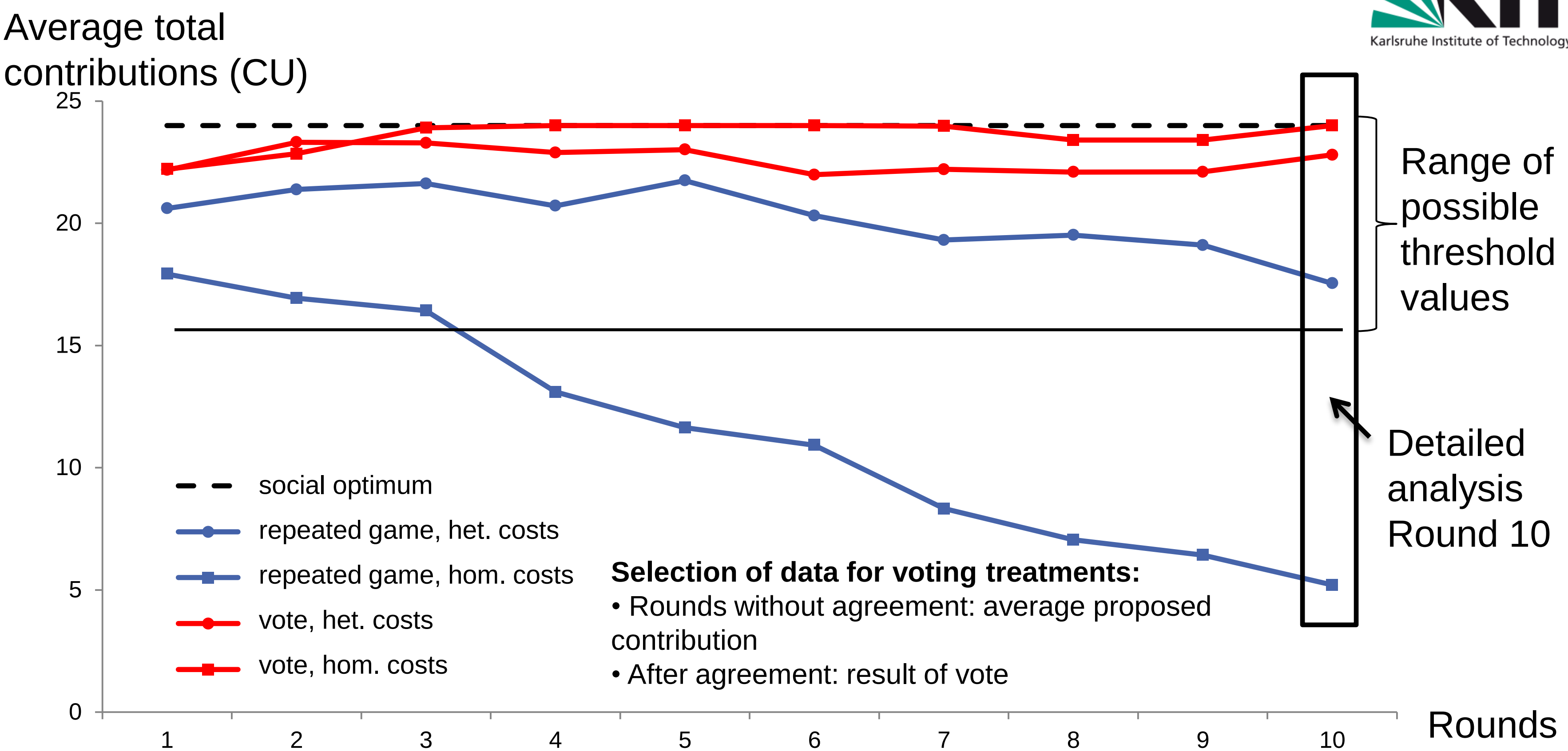
- Factors that hamper coordination on the threshold:
  - **Endowment heterogeneity** (e.g., Rapoport & Suleiman 1993)
  - **“Public bads”** framing (Sonnemans, Schram, Offerman 1998)
  - **Uncertainty**, the more the larger the range of possible threshold values (Suleiman, Budescu, Rapoport 2001)

Results

Total contributions at end of coordination process

Treatment		Inferior (Q < 16 CU)	Risky (16 ≤ Q < 24)	Optimal (Q ≥ 24)
Unanimous vote (bottom-up)	Hom	0	0	8
	Het	1	0	7
Repeated game (Round 10)	Hom	6	2	0
	Het	2	5	1

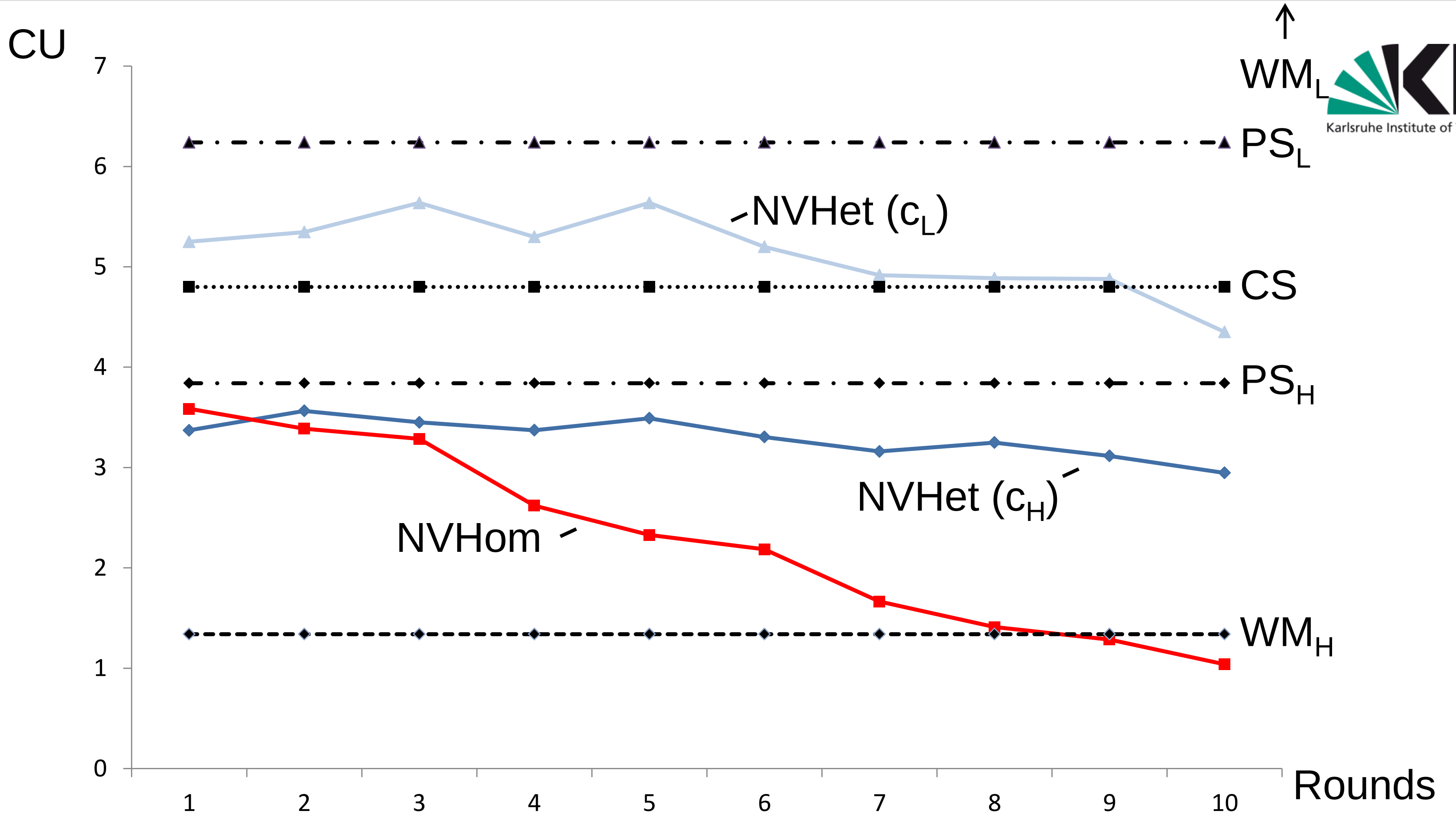
- Total contributions are more frequently optimal in voting treatments (two-tailed Fisher's exact: $p < 0.001$ (Hom), $p = 0.004$ (Het))
- Repeated game: Heterogeneous costs increase contributions (though not significantly: $p = 0.132$)
- But: Over all ten rounds, heterogeneous groups are significantly more often successful (i.e., reach the threshold in 5+ rounds) ($p = 0.041$)



Round-by-round comparison of total contributions

Unanimous vote: Proposals and results are close to social optimum.

Repeated basic model: Heterogeneous groups maintain high level of contributions. In homogeneous groups coordination often fails entirely (6 out of 8 groups).



Average individual contributions repeated game (no vote)

Heterogeneous costs: Individual contributions are closer to equal payoffs (PS) than welfare maximization (WM). Low-cost players prefer equal contributions (CS).

Homogeneous costs: Contributions converge to payoff-symmetrical Status Quo.

Summary

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- A binding unanimous vote achieves better coordination on the threshold than mere interaction in the repeated basic model.
- The subjects prefer a payoff-symmetrical outcome to an improvement of total payoffs.
- Heterogeneous marginal cost of contribution appear to improve coordination in the repeated game.
  → More observations needed to check robustness!
- The real question is:
  Why are homogeneous non-voting groups so unsuccessful?

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Cooperative regimes for future climate policy

Thank you for your attention!

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