Rewards and coordination for public goods

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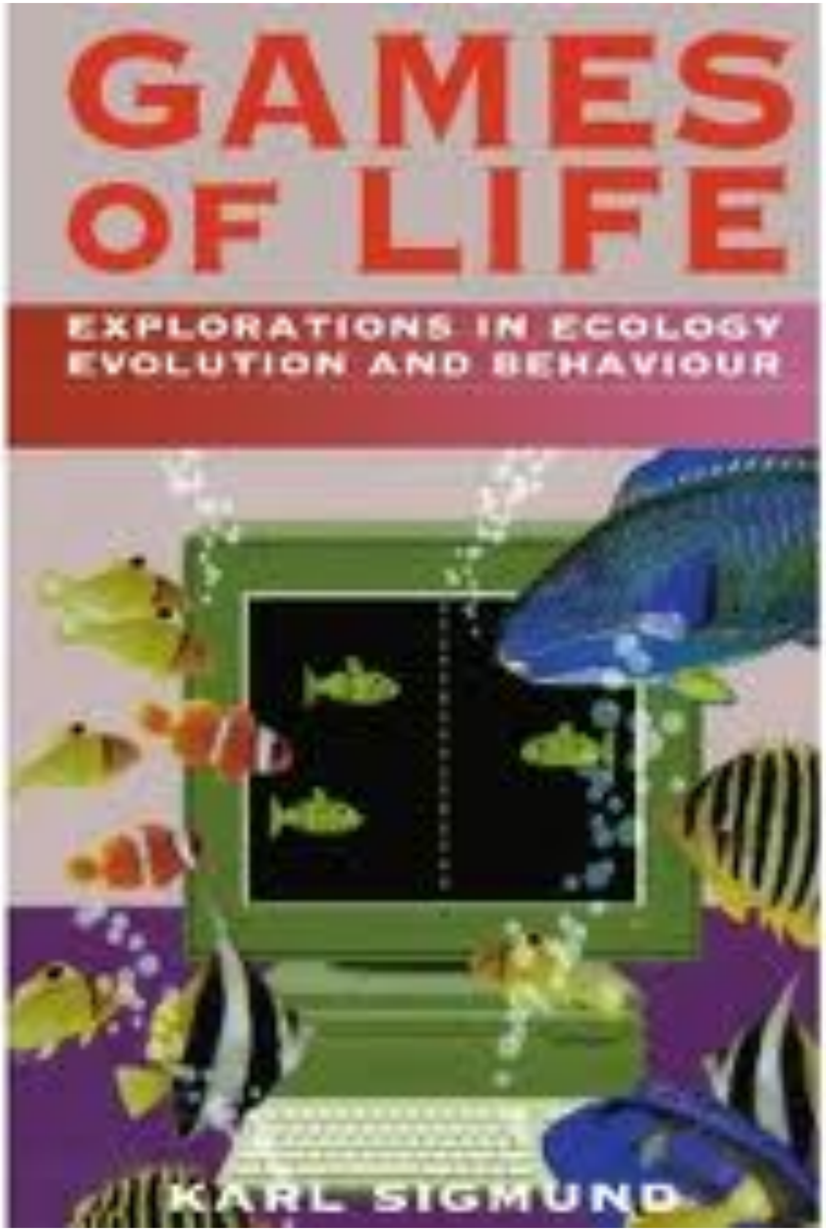
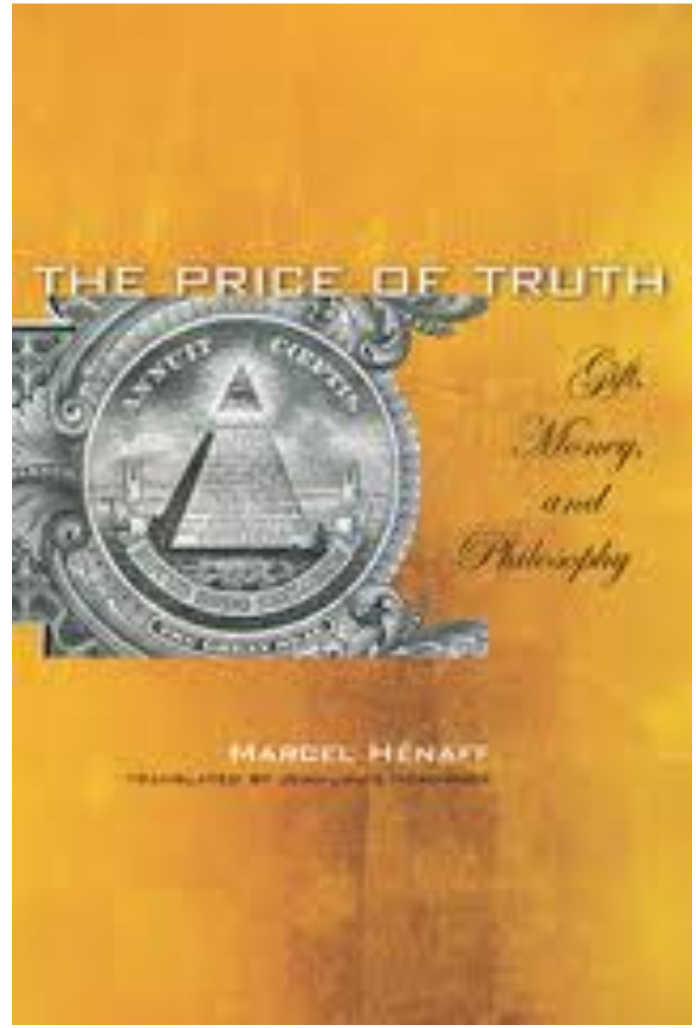

GAMES OF LIFE
EXPLORATIONS IN ECOLOGY EVOLUTION AND BEHAVIOUR
KARL SIGMUND

The systems of justice

- Marcel Hénaff (2010)
  ‚*The Price of Truth*', Stanford
- Reciprocity as justice
  Vengeance and ceremonial gift-giving
  Tit for tat
  Hunter-gather society
- Emergence of higher arbitrational instances
  Sacrifice and redistribution
  Gun for hire
  Farming society



Public goods and free riders

- **How can human societies based on the sacrifice and redistribution emerge?**
  -> Could the centralized mediating institution evolve through decentralized reciprocal interactions? [Ohsawa, *Gunzou*, 2012]

- A standard model -- public-good interaction
  Contributors voluntarily places presents in the center (‚meson‘); then these goods become shared equally among all members

- We shall start by tackling the free-rider problem
  - What can motivate the contributors?

Linear public-good games

- Group size $N > 1$
- Two strategies: cooperators (C) contrinute $c_1 > 0$, but defectors (D) do not
- Contributions accumulated are multiplied by $r_1 > 1$, and shared equally among *all* of the N members

- If all contribute, each receives payoff $c_1(r_1 - 1) > 0$

- **Defector-dominance**
  Assume $r_1 < N$. Hence, $c_1(1 - r_1/N) > 0$, and switching to defection is beneficial, whatever co-players do

Two steps for cooperation

- How to protect cooperation against mutant freeriders
  + stabilize a state in which all cooperate
  + top-down, deductive approach
  + basin of attraction, discrete, bistability
  + **punishment**

- How to inspire cooperation in a sea of freeriders
  + destabilize a state in which all defect
  + bottom-up, inductive approach
  + mixed strategy, continuous, coexistense
  + reputation and optimism, **rewards**, ...

Carrots and sticks

- Selective incentives, such as reward, punishment, and ostracism, are common tools to curve human behaviors

- Selective incentives are often costly
  -> Who pays for incentives?
  -> Which incentive scheme can best promote cooperation?
  [e.g., Hauert et al, *PNAS*, 2001; Sasaki et al., *PNAS*, 2012]

- Given the linear public good game (D-dominance),
  - Reward is good at inspiring cooperation
  - Punishment is good at stabilizing cooperation

Institutional sanctions and subsidies

- Exclusive control of sanction
  - discourage or prohibit informal punishment
  - stop infinite regression to higher-order incentives
- Separation of resource issues
  - severe penalties on second-order free-riders
    (e.g., tax- or draft-dodgers)
- More transcendental authority (*ex post* -> *ex ante*)

- '[B]etter formal institutions strengthen social norms of cooperation and limit antisocial punishment (Herrmann, et al. (2008)' [Gaechter, *Keio Economic Studies*, 2012]

Reward funds

[Sasaki & Unemi, *JTB*, 2011]

- A third strategy: rewarders (R) contrinute to PGGs and also $c_2 > 0$ to reward funds
- Cs and Ds do not contribute to rewarding
- Funds accumulated are multiplied by $r_2 > 1$, and shared equally among *all* Rs and Cs

- If no C, each R receives bonus $c_2(r_2 - 1) > 0$

- Assume that
  $c_2(r_2 - 1) - c_1 > 0$: Rs dominate Ds
  $r_2 < N$, wichi is $c_1(1 - r_1/N) > 0$: Cs dominate Rs

Individual payoffs in a linear PGG with rewards

$$f_D = \frac{c_1 r_1 i}{N}$$

$$f_C = \frac{c_1 r_1 (i+1)}{N} - c_1 + \frac{c_2 r_2 j}{i+1}$$

$$f_R = \frac{c_1 r_1 (i+1)}{N} - c_1 + \frac{c_2 r_2 (j+1)}{i+1} - c_2$$

i: the number of Rs and Cs within the $N-1$ co-players

j: the number of Rs within the $N-1$ co-players

Evolutionary dynamics

- Replicator dynamics: individuals switch preferentially to better strategies

$$\dot{x} = x\left(P_R - \overline{P}\right), \quad \dot{y} = y\left(P_C - \overline{P}\right), \quad \dot{z} = z\left(P_D - \overline{P}\right)$$

$x, y, z:$ the relative frequencies of Rs, Cs, Ds

$\overline{P} = xP_R + yP_C + zP_D:$ the average fitness over the population

- The expected payoffs for strategy S = C, D, R

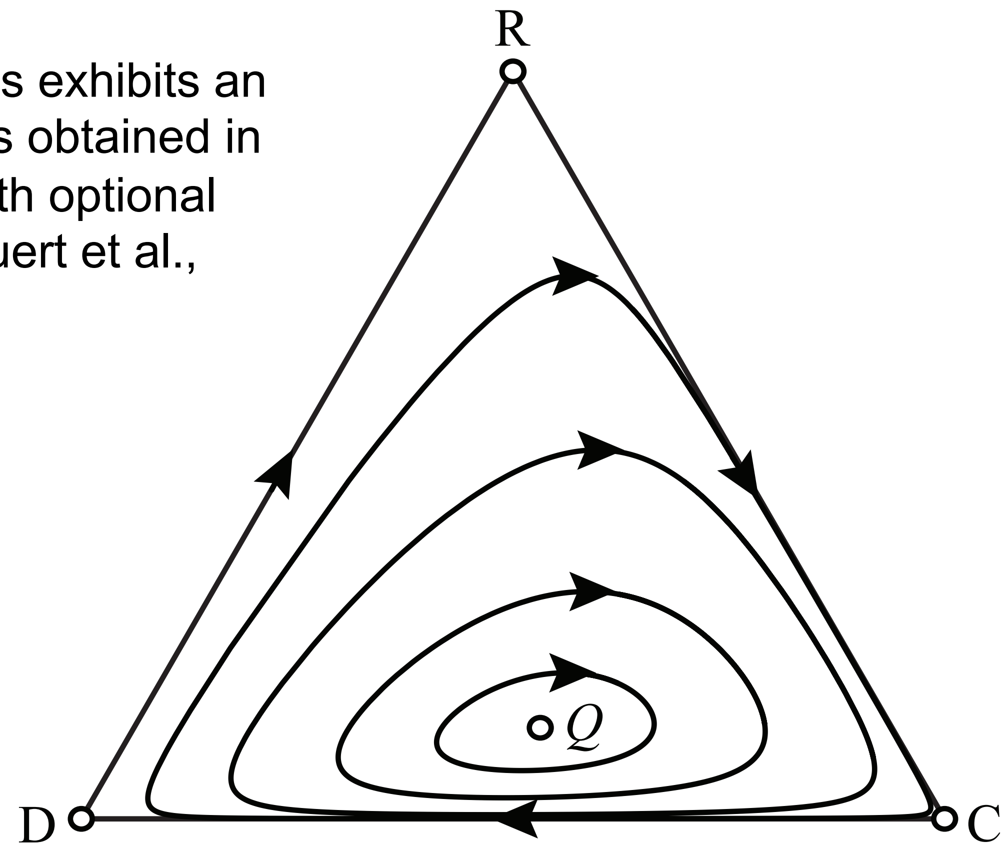
$$P_S = \sum_{i=0}^{N-1} \sum_{j=0}^{i} \binom{N-1}{i} \binom{i}{j} x^{i-j} y^{N-1-i} z^j f_S$$

infinitely large population -> multinomial distribution

Rock-scissors-paper cycles

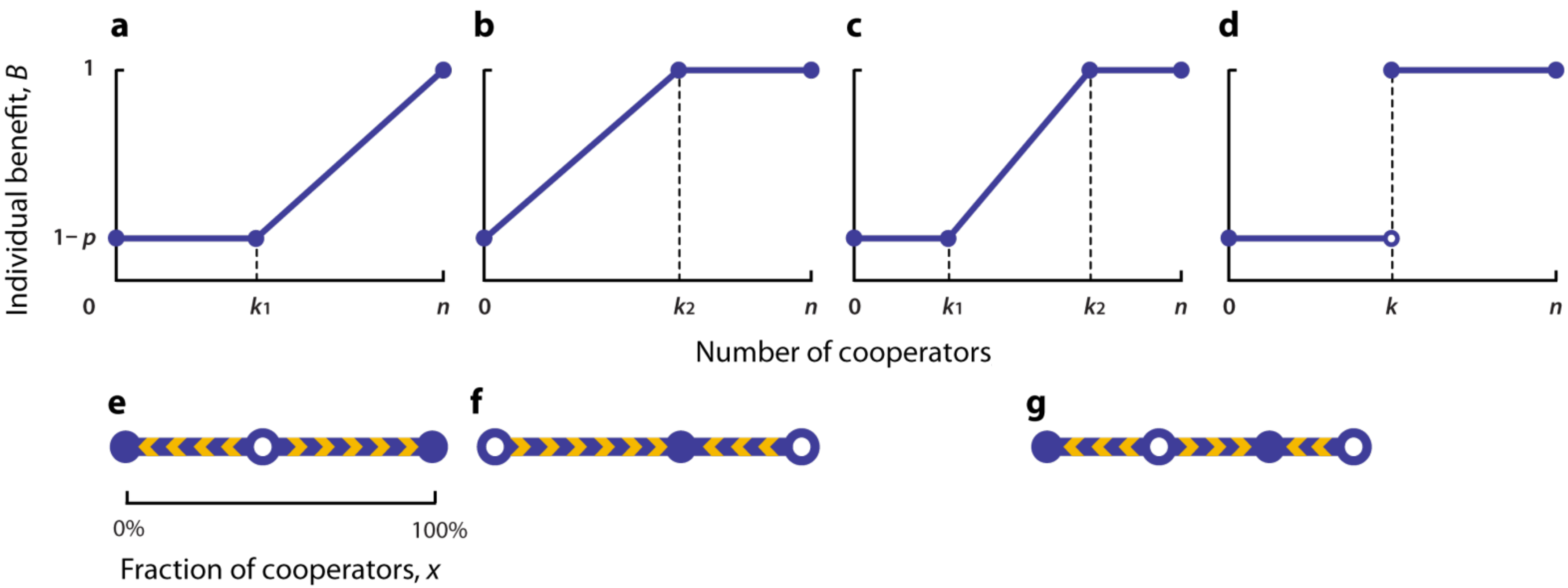
- If $c_1\left(1-\frac{r_1}{N}\right) < c_2(r_2-1),$

  the replicator dynamics exhibits an evolutionary cycling as obtained in the previous model with optional participation [e.g., Hauert et al., *Science*, 2002]



What if threshold public goods games?

- Minimalistic extension yet rich evolutionary scenarios
- The Individual benefit is given by piecewise benefit function *B* with respect to the number of contributors in the PGG stage



Let us focus on the PGG with a step-like benefit function, whereas there exist a wealth of literature [e.g. Santos & Pacheco, *PNAS*, 2011]

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The evolution of *n*-player cooperation—threshold games and ESS bifurcations

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Emergence of social cooperation in threshold public goods games with collective risk

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PNAS

Risk of collective failure provides an escape from the tragedy of the commons

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From group hunting to global warming, how to deal with contain at least M Cs (or equivalently, a collective effort of Mcb),

Climate negotiations under scientific uncertainty

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How does uncertainty about "dangerous" climate change affect the prospects for international cooperation? Climate negotiations usually are depicted as a prisoners' dilemma game; collectively, countries are better off reducing their emissions, but self-interest

which "there is a critical threshold between 350 and 550 p.p.m.v." (16). Our model can be interpreted as representing threshold uncertainty in this same way. Using the above reference values, our model suggests that countries can recognize that it is best

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Coordination and cooperation in asymmetric commons dilemmas

Marco A. Janssen · John M. Anderies · Sanket R. Joshi

Individual payoffs in a **step** PGG with rewards

$$f_D = B(i)$$

$$f_C = B(i+1) - c_1 + \frac{c_2 r_2 j}{i+1}$$

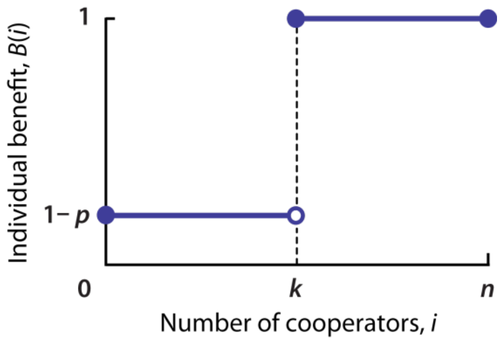
$$f_R = B(i+1) - c_1 + \frac{c_2 r_2 (j+1)}{i+1} - c_2$$

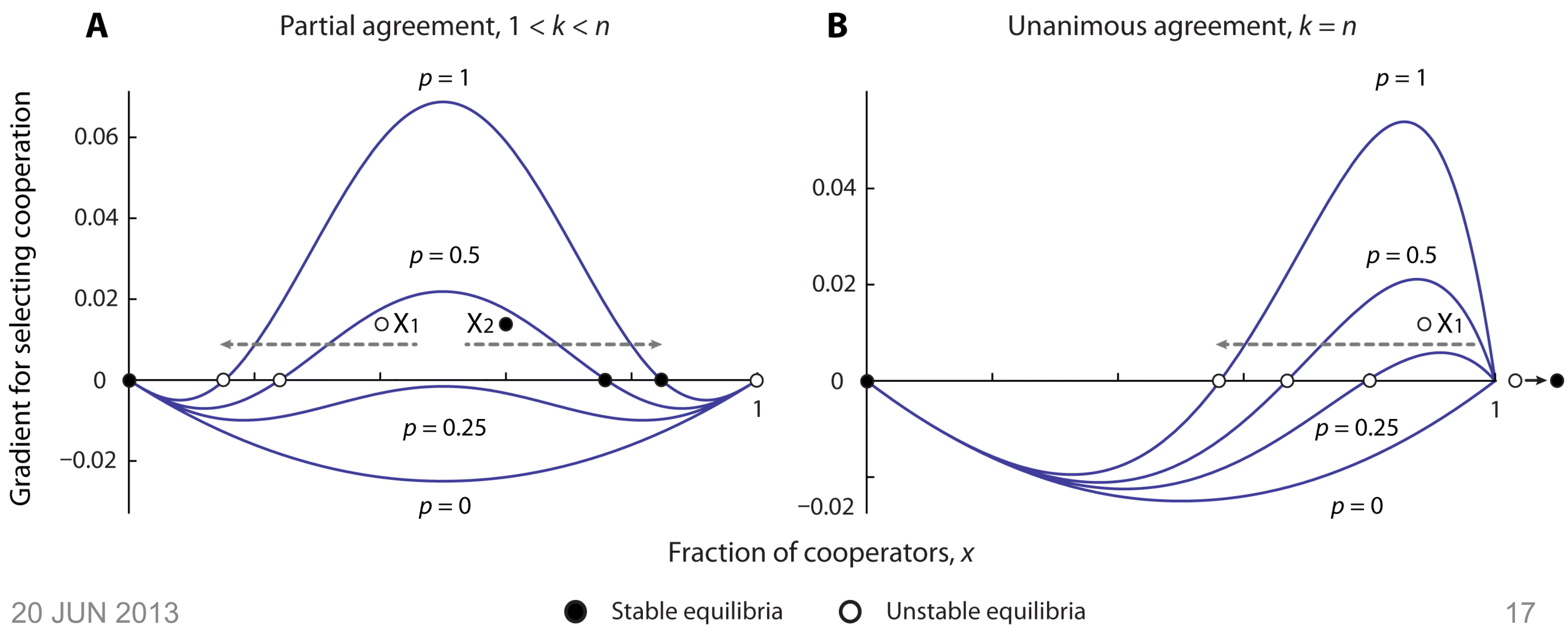
$$\text{where } B(i) := \begin{cases} 1 & \text{if } k \le i \le N \\ 1-p & \text{if } 0 \le i < k \end{cases}$$

i: the number of Rs and Cs within the $N-1$ co-players

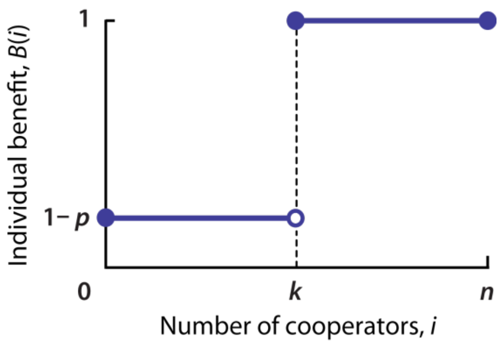
j: the number of Rs within the $N-1$ co-players

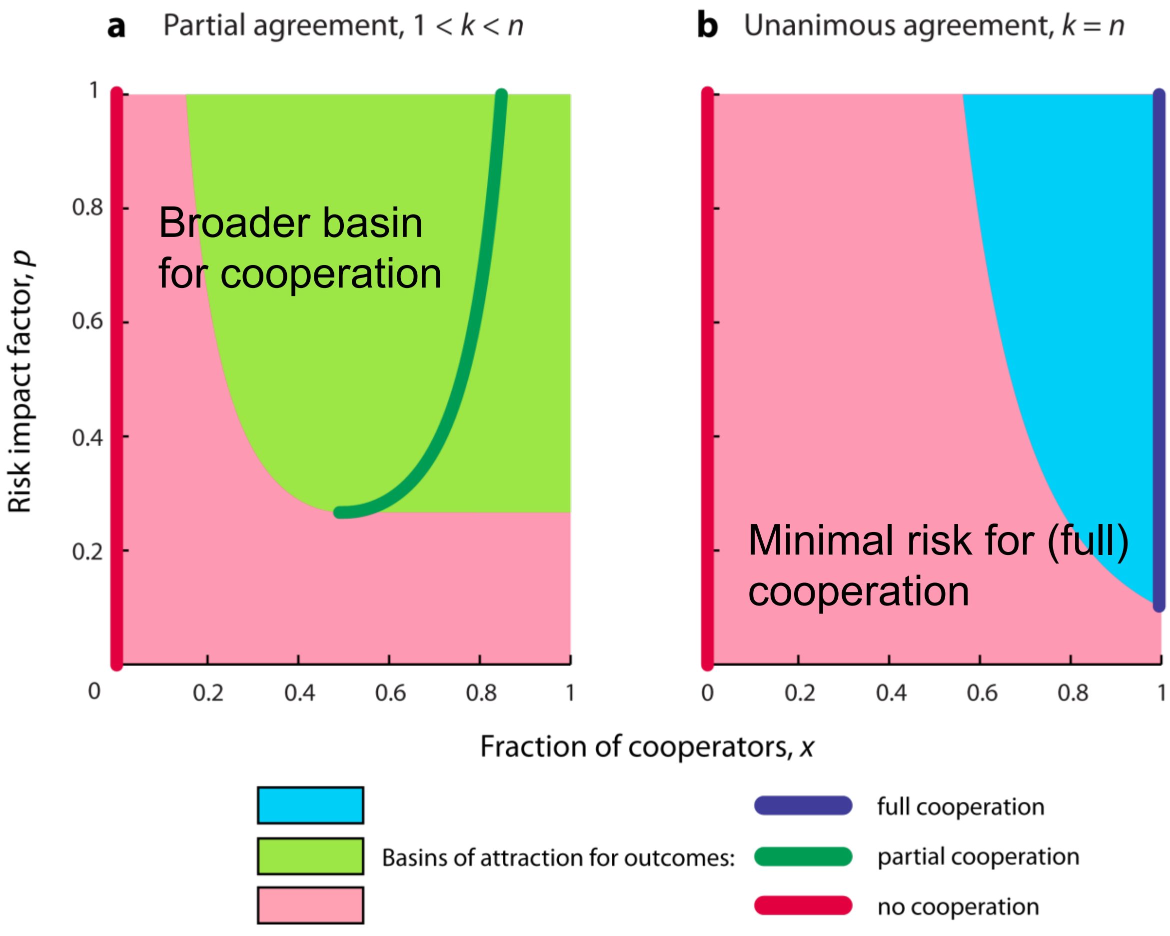
Step PGGs without reward funds
Replicator dynamics [e.g. Santos & Pacheco, *PNAS*, 2011]



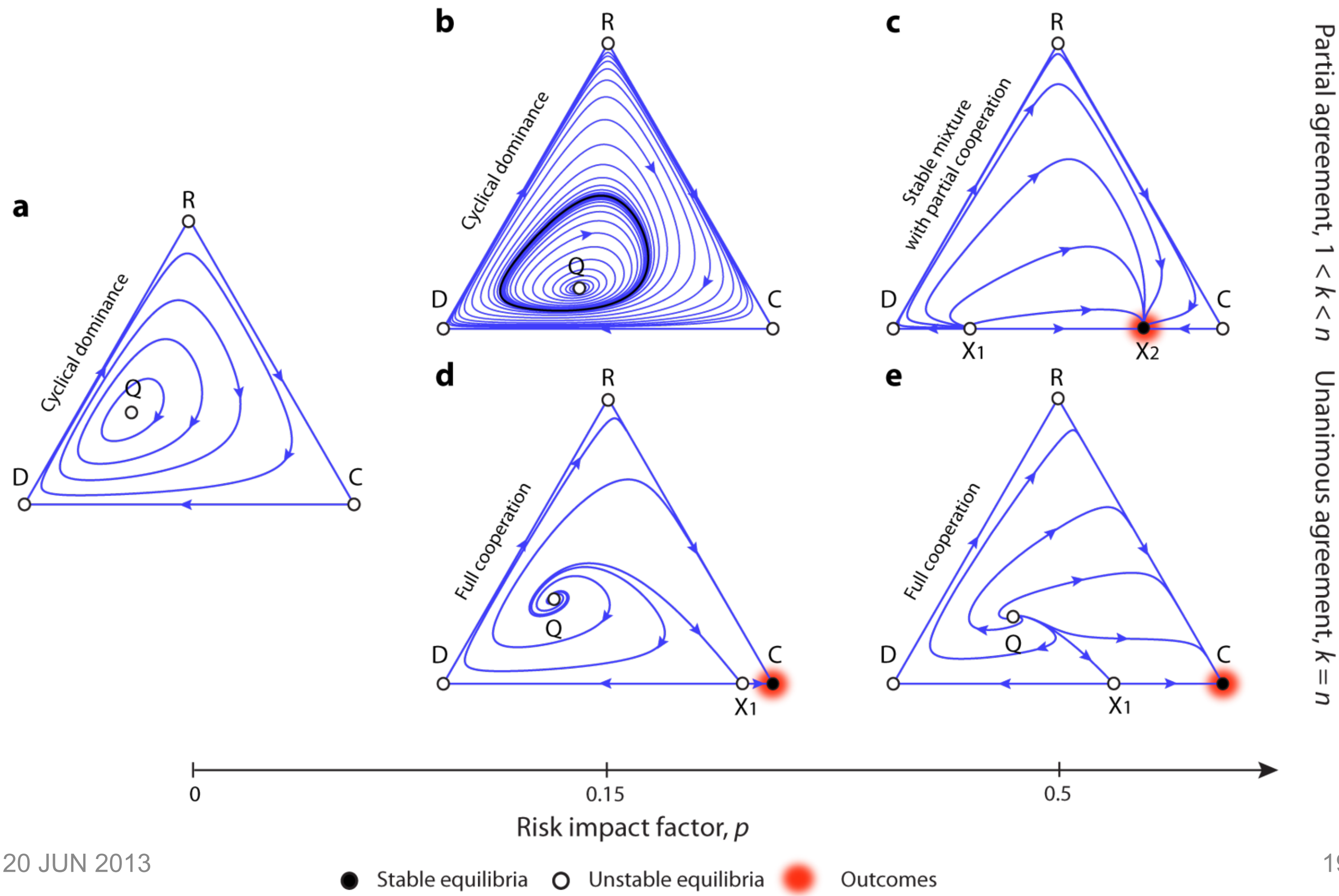


Step PGGs without reward funds
Bifurcation diagram





Step PGGs with reward funds
Replicator dynamics [Sasaki & Uchida, *in progress*]



Summary and discussion

- Reward funds: an evolutionary bypass, vanishing media
- Reward funds are applicable even when participation in the focal joint enterpise is obligatory (c.f. optional participation)
- Reward funds can lead to
  (i) rock-paper-scissors cycling for the previous D-dom. game
  (ii) full cooperation for the previous coordination game
- In (ii), once the Pareto equilibrium is stabilized, it also becomes globally stable with reward funds
- Step PPGs: when the level of collective risk is relatively low, the only unanimous agreement is attainable

The Increased Risk of Joint Venture Promotes Social Cooperation

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Abstract

The joint venture of many members is common both in animal world and human society. In these public enterprizes, highly cooperative groups are more likely to while low cooperative groups are still possible but not probable to succeed. Existent literature mostly focuses on the traditional public goods game, in which cooperators create public wealth unconditionally and benefit all group members unbiasedly. We here institute a model addressing this public goods dilemma with incorporating the public resource foraging failure risk. Risk-averse individuals tend to lead a autarkic life, while risk-preferential ones tend to particip

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Does a membership fee foster successful public good provision? An experimental investigation of the provision of a step-level collective good

Mohamed Ali Bchir · Marc Willinger

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Linear PGGs with reward funds

- Difference of the expected payoffs (y: the relative frequency of Ds)

$$P_C - P_R = c_2\left(1 - \frac{r_2}{N}\frac{1-y^N}{1-y}\right) =: F(y),$$

$$\text{with no rewarders } (z=0),\ P_D - P_C = c_1\left(1 - \frac{r_1}{N}\right) =: \sigma$$

- The replicator system is rewritten as

$$\dot{f} = -f(1-f)F(y)$$
$$\dot{y} = y(1-y)\left[\sigma - c_2(r_2 - 1)f\right]$$

by using $f := z/(x+z)$ where x and z denote the relative frequencies of Cs and Rs, respectively