Toulouse
School of
Economics

Evolution of Economic Behavior

TSE M1 – Semester 1

October 2019

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Week 5: Game Theory in Biology and Economics.

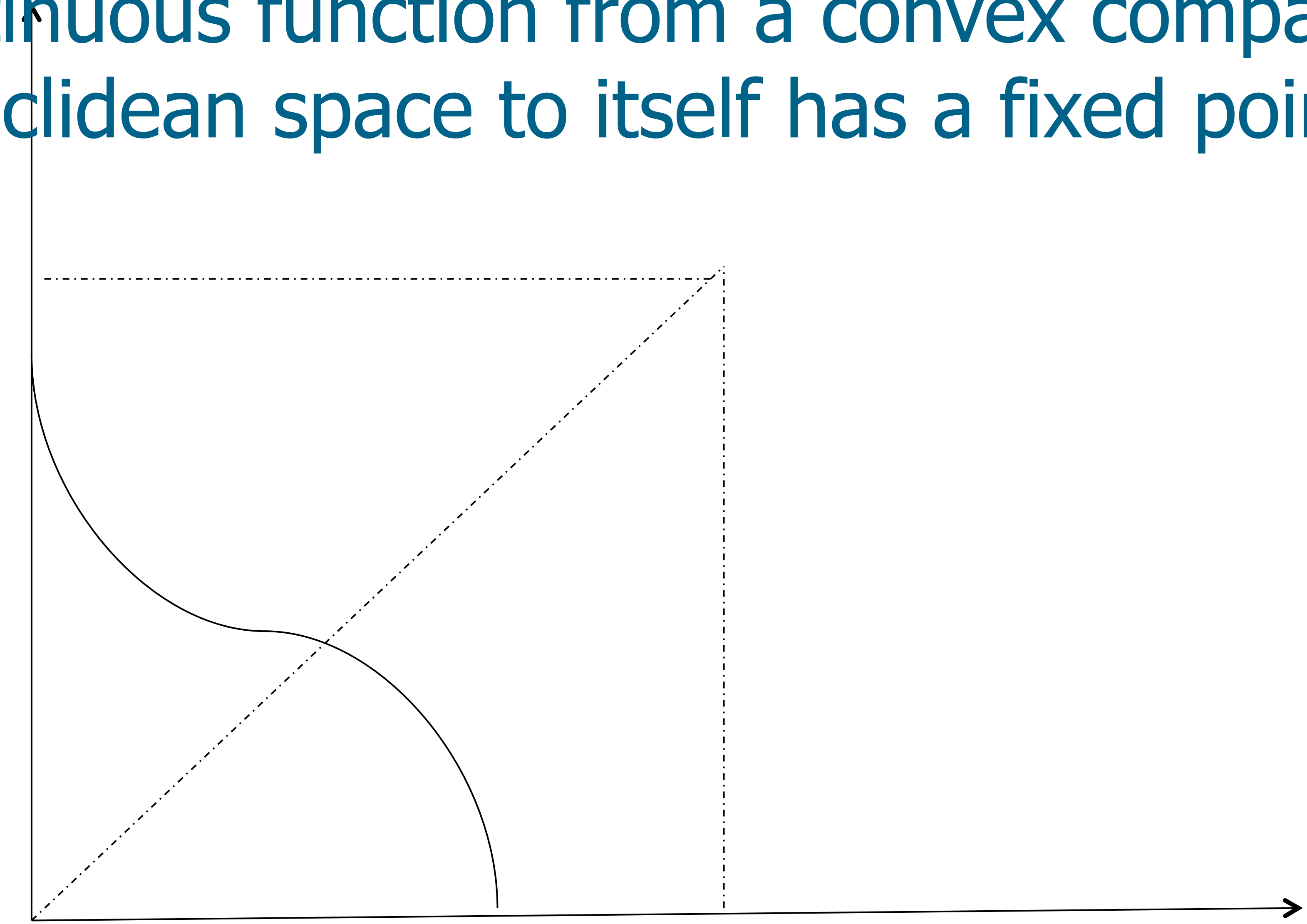
Outline

- The problem of strategic behavior
- The economic model: Nash equilibrium and fixed point analysis
- The biological model: evolutionary stable strategies
- Mixed strategy equilibria
- Foresight and commitment
- An example: explaining social cooperation

The problem of strategic behavior

- Strategic behavior involves rational decision makers anticipating the behavior of other rational decision makers.
- For a long time the problem of “infinite regress” seemed to block the way to an understanding of the principles of rational strategic behavior, though Cournot (1838) made a contribution whose importance was not fully appreciated till much later.
- Zero-sum games provided a partial way out (von Neumann-Morgenstern, 1944).
- John Nash (1951) provided the solution for all games with finite strategy spaces, in terms of a fixed point argument.

A fixed point argument: the Brouwer theorem (continuous function from a convex compact subset of Euclidean space to itself has a fixed point)



An example: Cournot equilibrium

- N firms, $i = 1,\ldots,n$
- Homogeneous product, constant marginal cost
- P = a - bq is inverse demand
- Representative firm chooses output q to maximise:

$$\pi_i = \left[a - b\left(\sum_{j=1}^{N} q_j \right) \right] qi - c.q_i$$

Cournot and Bertrand equilibria

- N firms, i = 1,…,n
- Homogeneous product, constant marginal cost
- P = a - bq is inverse demand
- *Taking others' output as given* (Cournot):

$$\pi_i = \left[a - b\left(\sum_{j=1}^{N} q_j \right) \right] qi - c.q_i$$

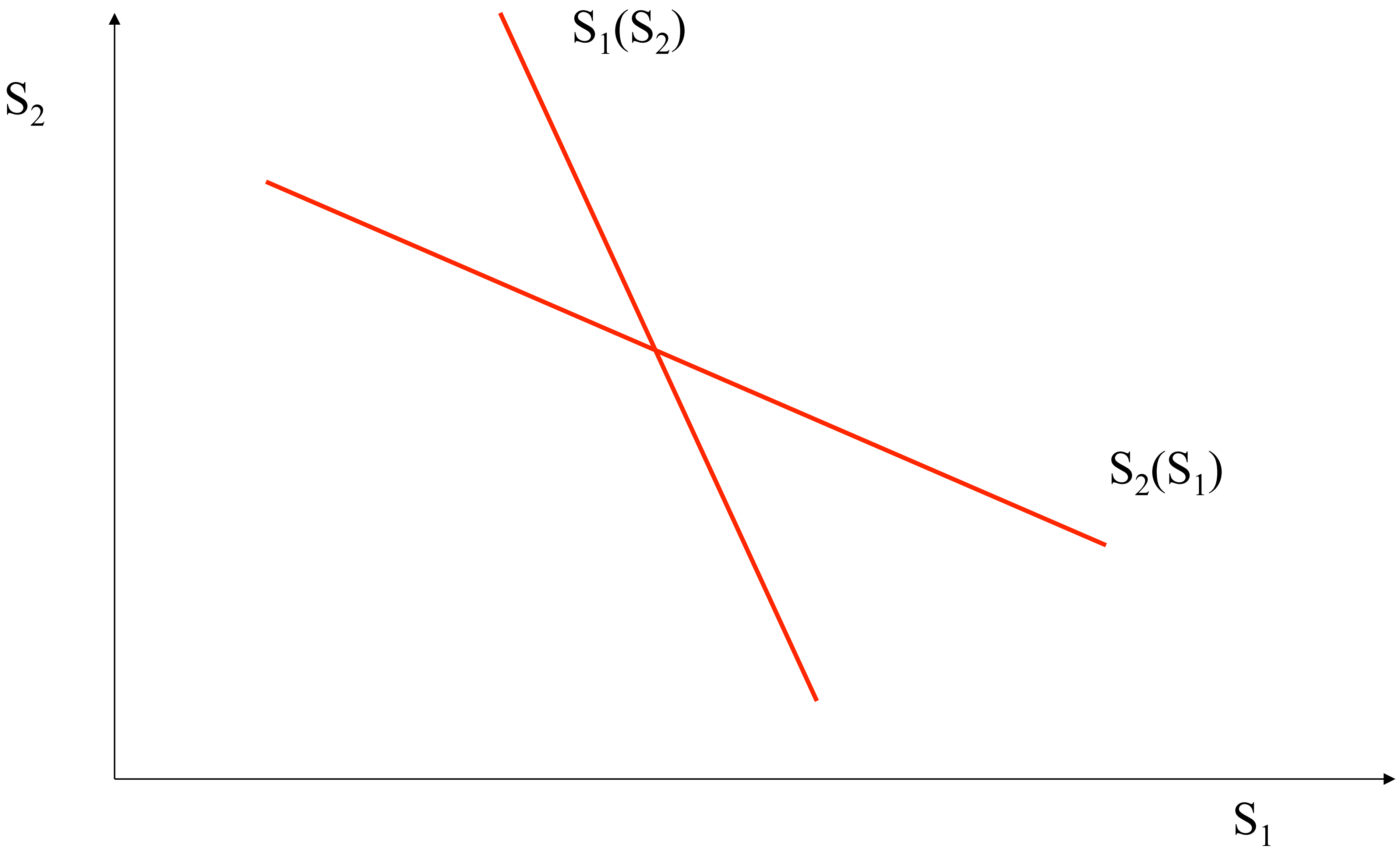
First-order conditions:

$$0 = \frac{\partial \pi_i}{\partial q_i} = a - 2bqi - b\sum_{j \neq i} qj - c$$

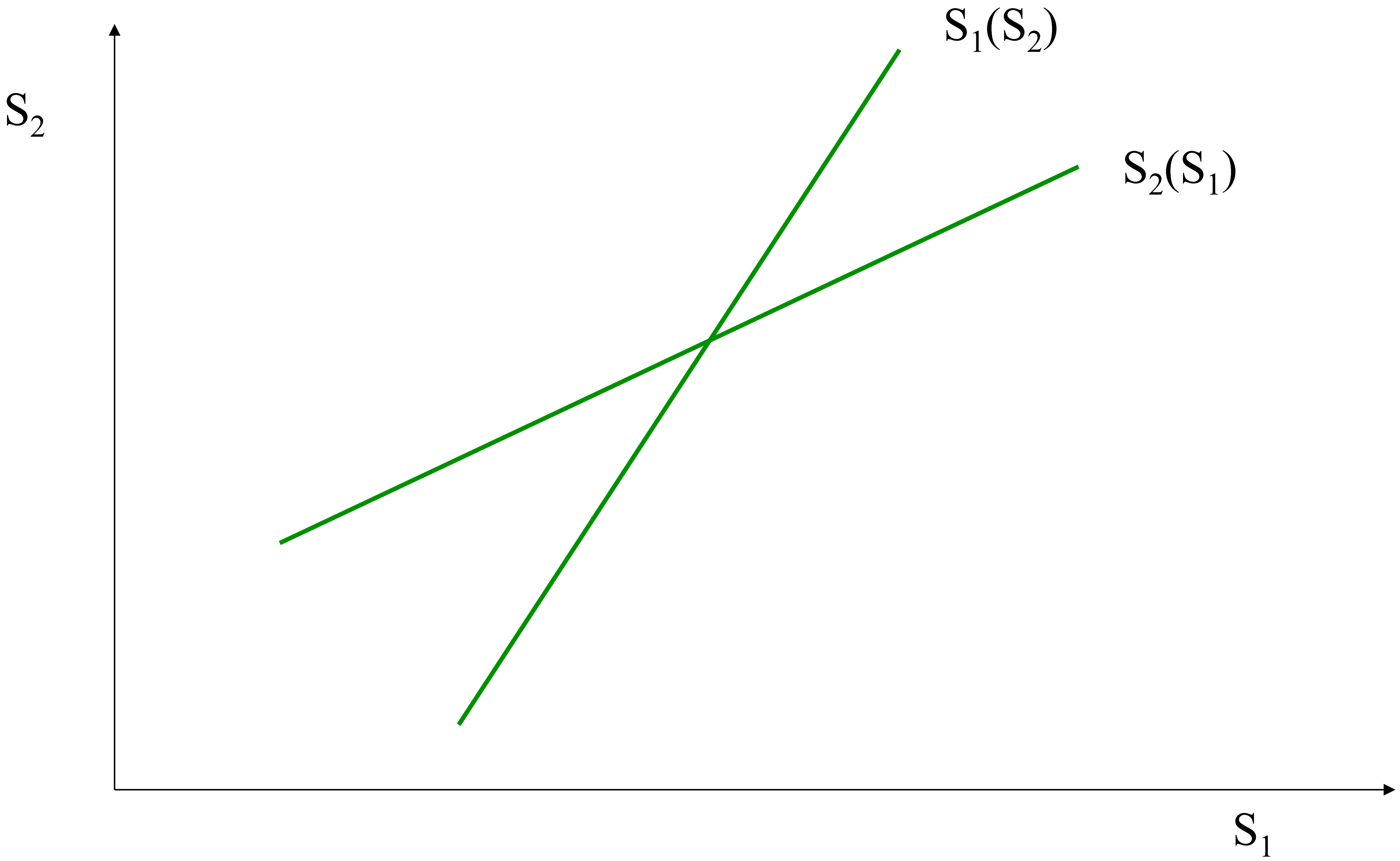
Expressed as a best-response (or *reaction*) function:

$$qi = \frac{a - c}{2b} - \frac{1}{2}\sum_{j \neq i} qj$$

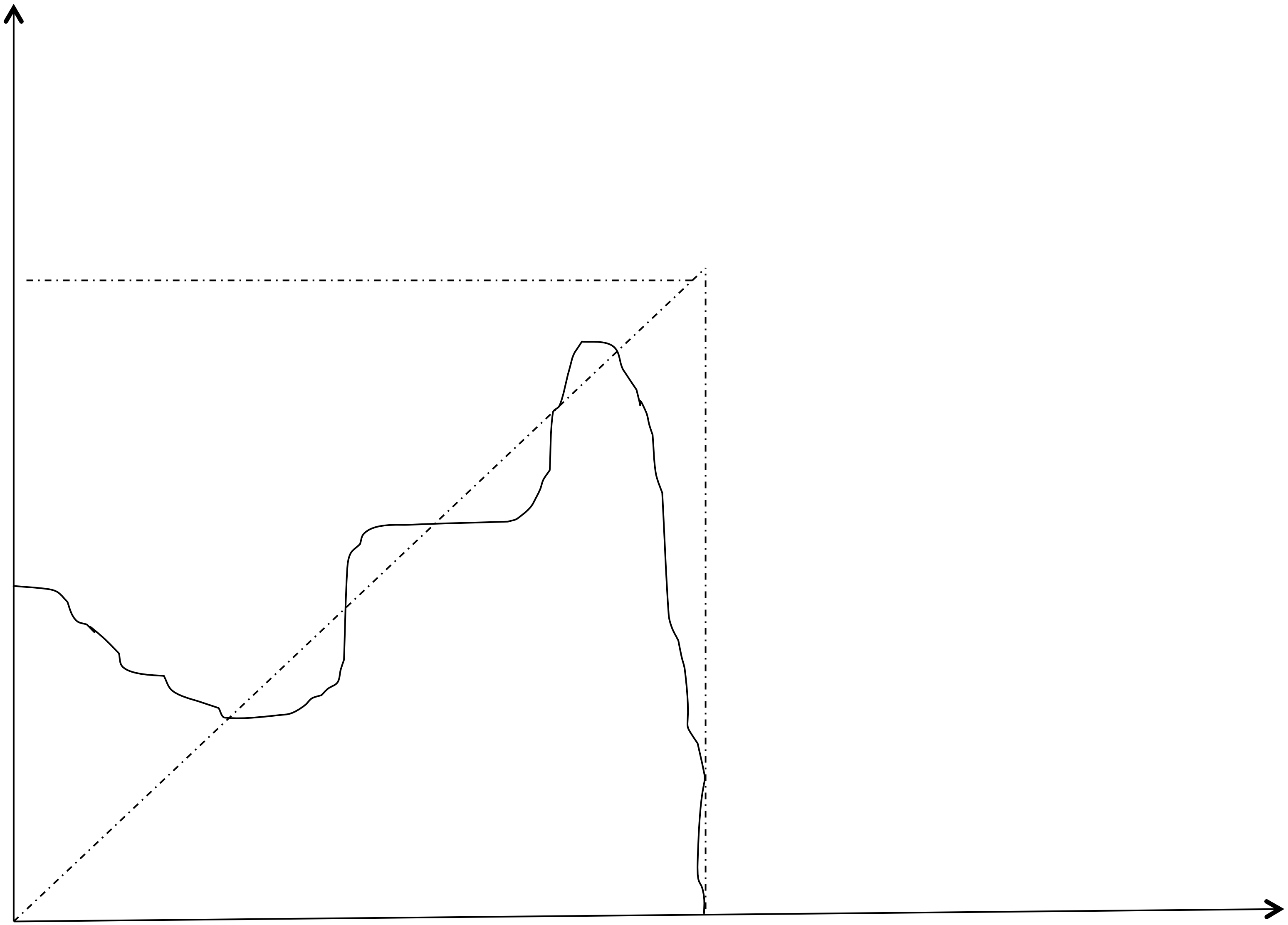
Strategic substitutes:



Other settings may involve strategic complements:



Multiple fixed points



A coordination game

Player 2:

Player 1:	A	B
A	2 2	1 -1
B	-1 1	5 5

Evolutionary Stable Strategies (ESS)

- Developed by Maynard Smith and Price (1973, Nature)
- An ESS is a strategy that, if adopted by the whole population, cannot be invaded by any mutation that is initially rare
- Very similar to Nash equilibrium (but not identical)
- But – an important qualification – the strategies are behaviors defined in conditional-response terms, not instances of optimization
- Natural selection does the optimizing, not the individual

A prisoners dilemma (a single Nash equilibrium that is also an ESS)

Player 2:

		High price	Low price
Player 1:	High price	2 2	3 -2
	Low price	-2 3	0 0

Harm They Neighbor (two Nash equilibria but only one ESS)

Player 2:

Player 1:	A	B
A	2 (upper right) 2 (lower left)	2 (upper right) 1 (lower left)
B	1 (upper right) 2 (lower left)	2 (upper right) 2 (lower left)

Mixed strategy equilibria

- Classic example: penalty kicks in football
- Hawk-dove game in biology vs chicken in economics
- Is this due to randomization between strategies or to strategy polymorphism?

Hawk-Dove game (an anti-coordination game)

Player 2:

		A	B
Player 1:	A	0 0	1 -1
	B	-1 1	-10 -10

Foresight and commitment

- Natural selection has no foresight
- This is usually considered a disadvantage – but it is not always so
- The foresight of cognitive processes weakens their commitment power – threats and promises may lack credibility
- Sometimes inflexible strategies are adaptive because they aid commitment

An example – explaining social cooperation

- Selfish individuals face a constant temptation to behave non-cooperatively
- The literature on repeated games has tried to explain why they might nevertheless behave "as if" they were intrinsically cooperative (self-interest with a long time horizon)
- A more recent literature (Bowles, Gintis and others) claims that individuals are not selfish but "pro-social"; there is much experimental evidence for this
- The challenge is then to explain how such pro-social behaviors could have evolved by natural selection

Some highlights

- The theory of evolutionary « mistakes »
- Multi-level selection theory
- The ingredients: positive sorting and strong payoffs to group interactions
- An example: warfare makes altruism possible? (Bowles, Choi & Hopfensitz, JTB 2003)
- A further development: the coevolution of altruism, parochialism and war (Bowles & Choi, Science 2007).

Consider a model a population in which individuals may be either Altruistic or Not and either Tolerant or aggressive (Parochial) towards other groups (these are behaviors, not preferences)

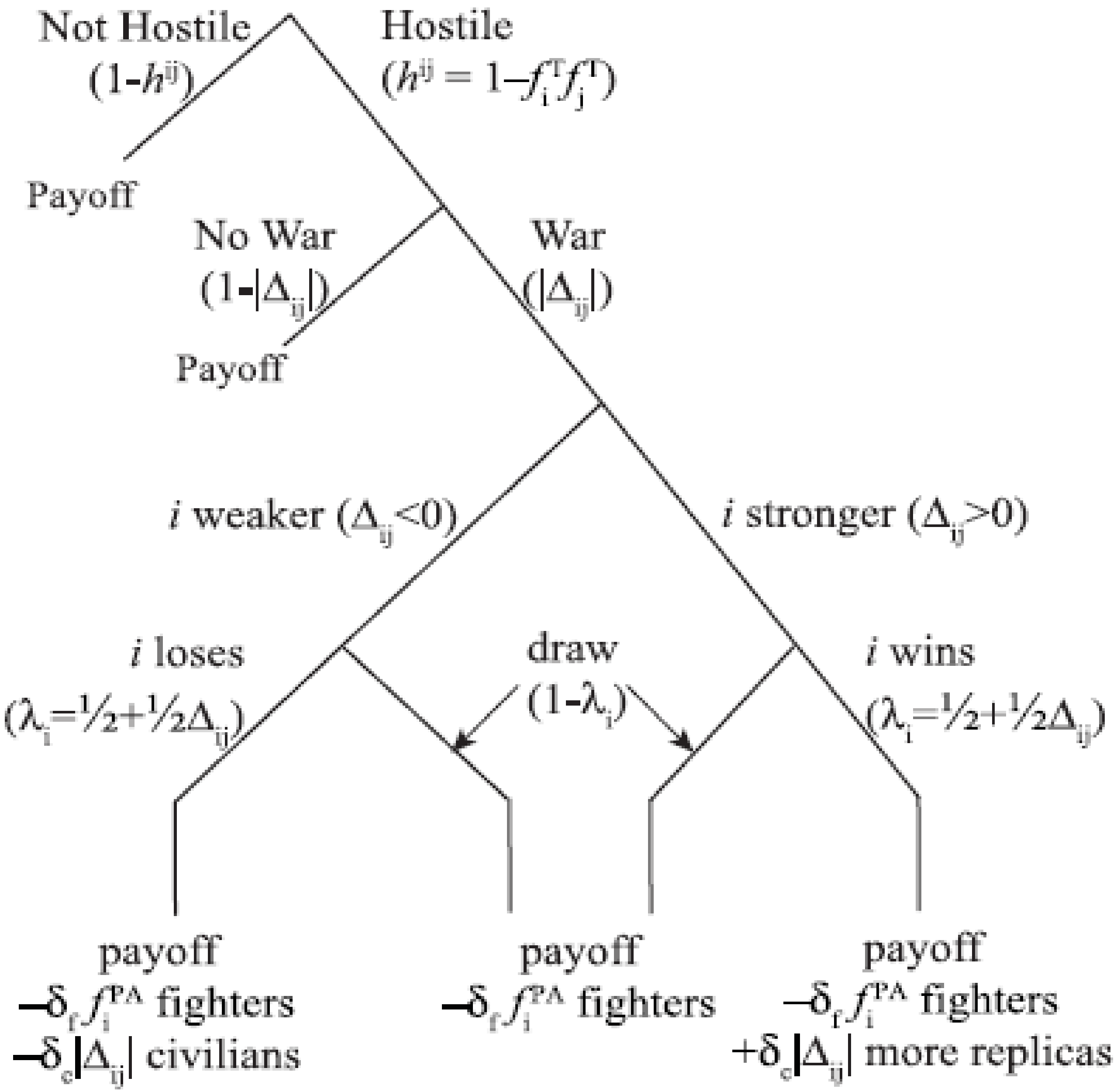
	Parochial	Tolerant
Altruist	PA	TA
Not	NP	NT

- A's contribute to the fitness of other group members at a cost to themselves
- Only the PA's fight wars.
- P's induce hostilities and forgo the benefits of peaceful interactions with other groups enjoyed by the T's

Within-group interactions: selection against A's and Ps

	Parochials	Tolerant
Altruist	$bf_i^A - c$	$bf_i^A - c + g\, n_j f_j^T$
Not Altruist	bf_i^A	$bf_i^A + g\, n_j f_j^T$

Between-group interaction game tree: frequent interactions may favor APs

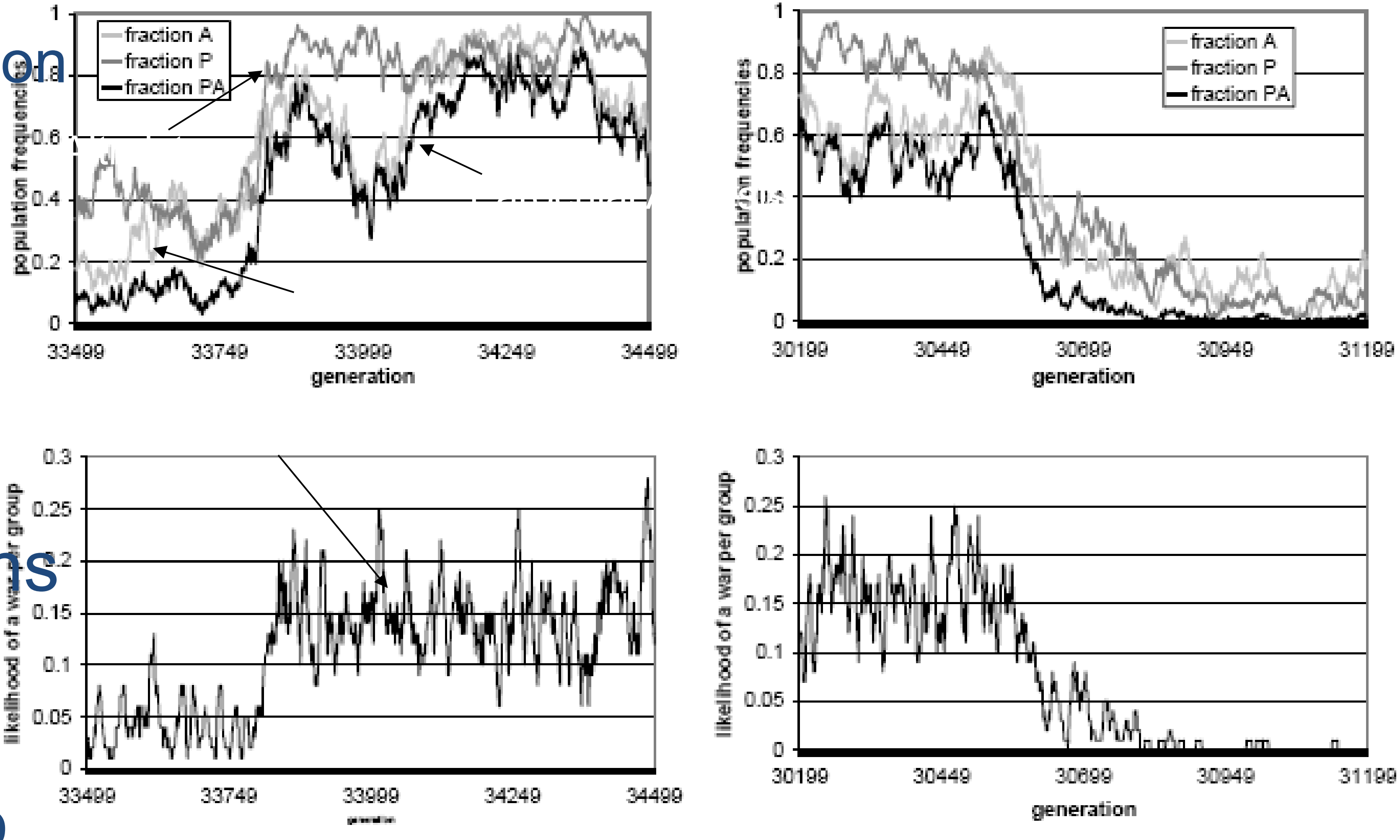


The model parameter values (per generation, where relevant)

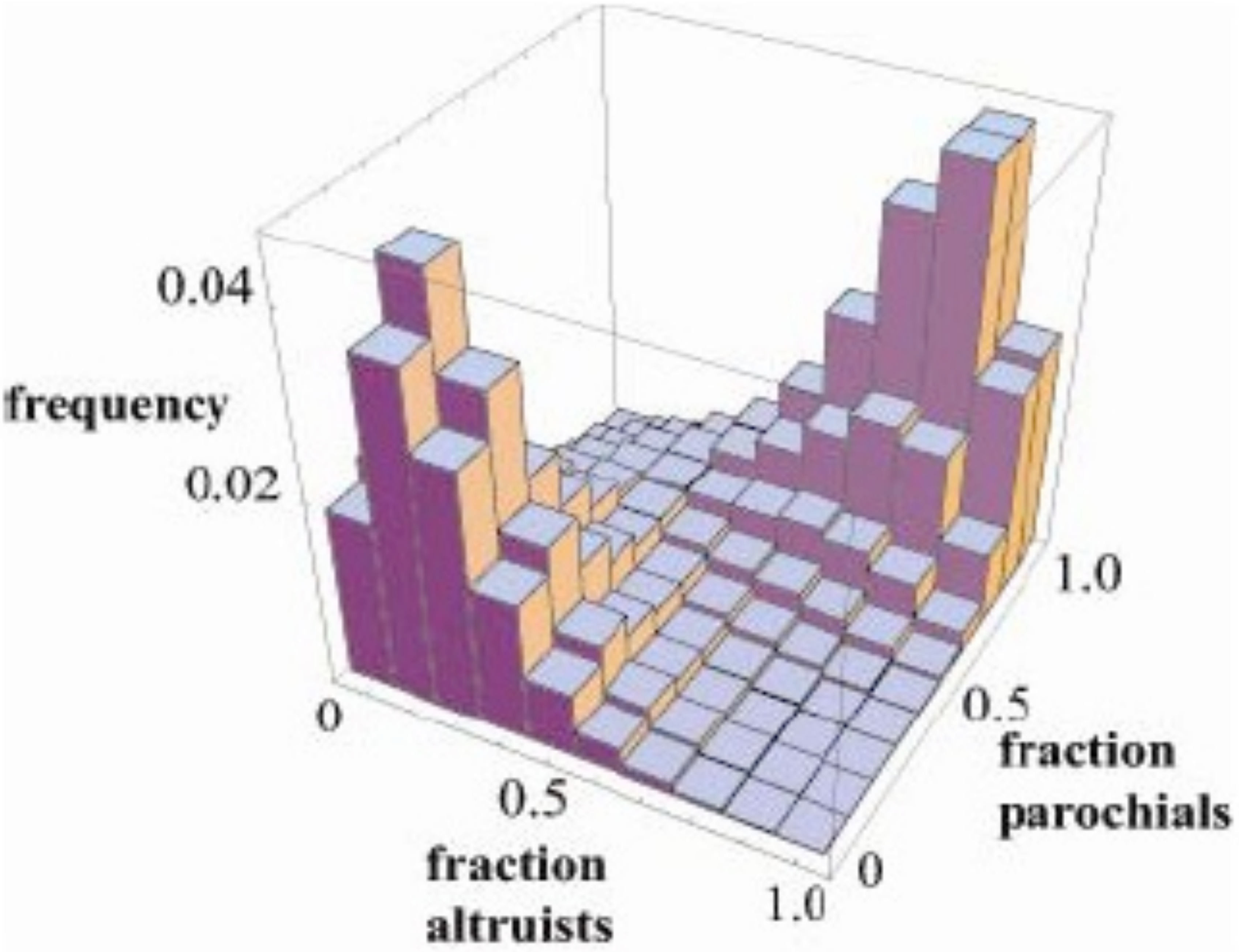
- # of groups = 20
- Group effective size =26 (i.e. census size 70)
- Mutation =0.005
- Two loci, two alleles at each locus, full recombination
- Between group island (random) migration =0.25
- Benefits and costs: b=0.02, c=0.01, baseline fitness=1
- Benefit from peaceful interaction: g=0.001
- Between group interactions per generation: k=1
- Fighters' mortality in warfare = 0.14

The co-evolution of altruism, parochialism, and war

Shown: transitions from selfish peace to altruistic war (and back)



An empirically estimated stationary (ergodic) distribution



Key features

- Behavior that has commitment value has a certain inflexibility
- Purely calculative Bayesian cognitive mechanisms have difficulty explaining such behavior
- Biological mechanisms can help – there are metabolic and developmental constraints that provide the necessary inflexibility
- Adaptive behavior is the right mix of commitment and flexibility, and natural selection has repeatedly found solutions of this kind

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Economics for the Common Good