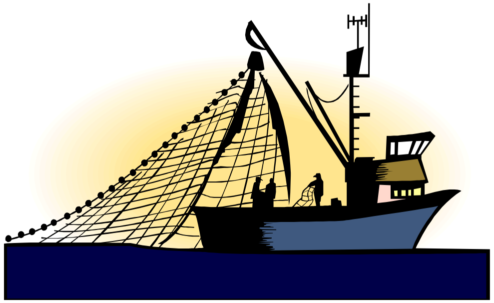
A Great Fish War Model With Asymmetric Players

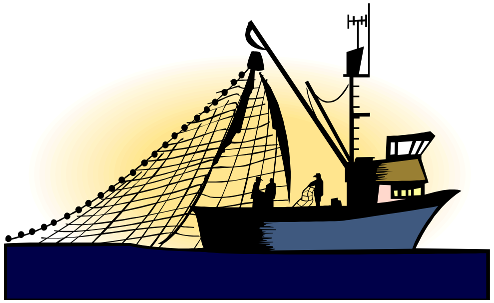
Michèle Breton & Michel Y. Keoula
GERAD and HEC Montréal

Fourth Workshop on Game Theory in Energy, Resources and Environment, November 2012

Motivation



- Great Fish War: a parsimonious model used extensively to analyze open-access problems in fisheries
  - Coordination is Pareto-improving
- Cooperative models:
  - Trigger strategies (Hämäläinen *et al.* 85, Cave 87, Benhabib & Radner 92)
  - Incentive strategies (Ehtamo & Hämäläinen 93)
  - Transfers (Pintassilgo *et al.* 10)



Motivation

- Partial coordination
  - NAFO (12 members), WCPFC (25 members), ICCAT (47 members)
- Non-cooperative setting yields grim results – unless additional mechanisms are used
  - First mover advantage (Kwon 06)
  - Farsightedness (Breton-Keoula 12)
  - Punishments (Lamantia)
  - Asymmetry?

Asymmetry

- Parameters
  - Cost of fishing (Clarke 90, Pintassilgo et al. 10)
  - Discount rates (trade-off between immediate consumption and investment in stock)
- Challenge: aggregation of heterogeneous time preferences (Gollier & Zeckauser 2005)
  - Munro 78, Plourde & Yeung 89: Time inconsistent solutions
  - Houba 00: 2 players, sequential bargaining solution
  - Denisova & Garnaev 08: equal sharing rule, various information structures without profitability issues

Time preference and discounting

- Discounting future utilities
  - Pure time preference / expected wealth growth with decreasing marginal utility
  - Wide variations in own and future generation's future welfare valuation
- Resource management objectives
  - Disagreement, asymmetric access, development stage, returns on investment
- Social planning and altruism
  - Ethical concerns
  - Multi-generation models with altruism (Novak 06)

This paper

- Time consistent cooperative solution with heterogeneous time preferences
- Characterization of Pareto-efficient sharing rules
- Coordination game: equilibrium strategies and coalition stability for coalition vs. fringe model
  - Simultaneous moves
  - First-mover advantage

Outline

- The coalitional Great Fish War Model
- Equilibrium solutions (Non-cooperative, cooperative, partial coordination)
- Coalition profitability and stability
- Conclusion

Great Fish War Model

Assumptions

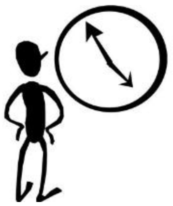
Bio-economic model

Feedback strategies and value function

The coalition vs fringe model

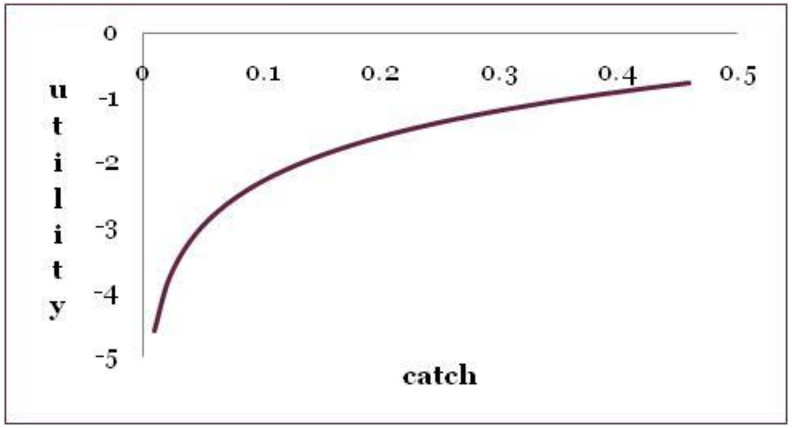
Key assumptions

- Players have different time preferences δ

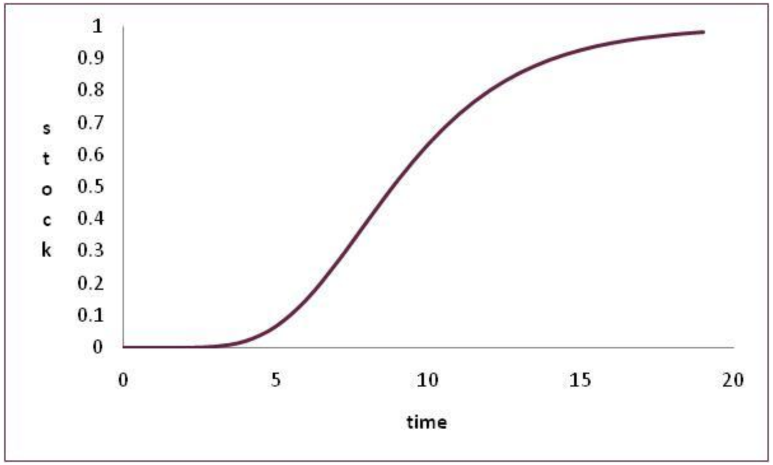


- Only one coalition forms
- There is no transfer of harvest between members
- Players are characterized by their strategic importance γ

Bio-economic model



$$u(x) = \log x$$



$$s_{t+1} = s_t^{\alpha}$$

Value function

$$V_{[x,y]}(s) = \log x + \delta V_{[x,y]}(y^{\alpha})$$

catch

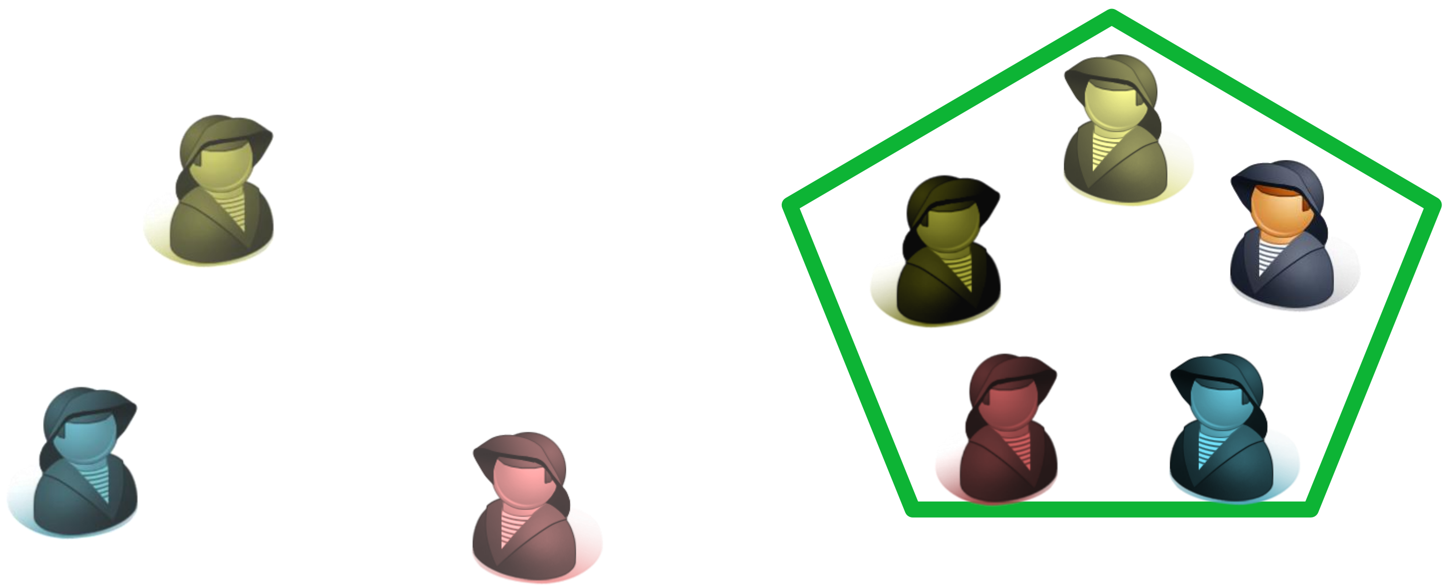
Investment
(residual stock)

If the catch and investment are both stationary linear functions of the stock, then the value function takes the log-linear form

$$V(s) = A + \frac{1}{1-\alpha\delta}\log(s)$$

The coalition versus fringe model

- Players of type 1 to *m* maximize their joint total discounted payoff
- Players of type *m*+1 to *M* maximize their individual payoff



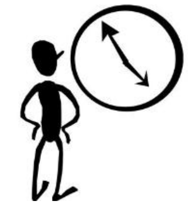
Equilibrium solutions

Competitive equilibrium

Cooperative equilibrium

Partial coordination

The bionomic discount rate


Low β

$$\frac{1-\alpha\delta_i}{\alpha\delta_i} \equiv \beta_i^{-1}$$

- In all cases, we obtain that optimal harvesting and investment strategies are linear in the stock
- $x_i(s)=h_i s$ and $y(s)=qs$ and consequently

$$V_i(s) = A_i + (1+\beta_i)\log(s)$$

$$A_i = (1-\delta_i)^{-1}\left(\log h_i + \beta_i \log q\right)$$


High β

The competitive solution

- Each player’s share of the total harvest is proportional to her bionomic discount rate
- The total harvest is directly related to the average of the bionomic rates
- Patient players always harvest less than impatient players, and their long-term payoff is lower

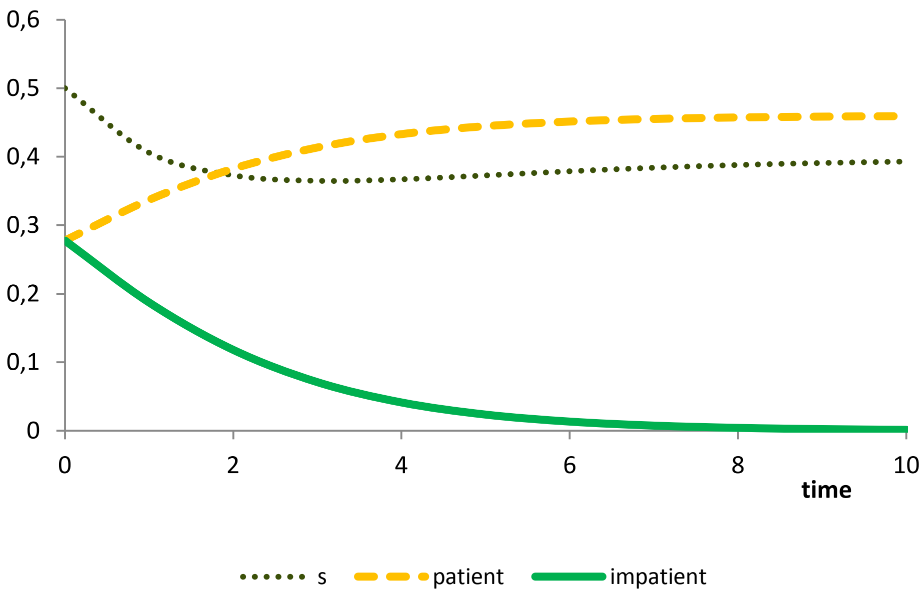
The cooperative solution

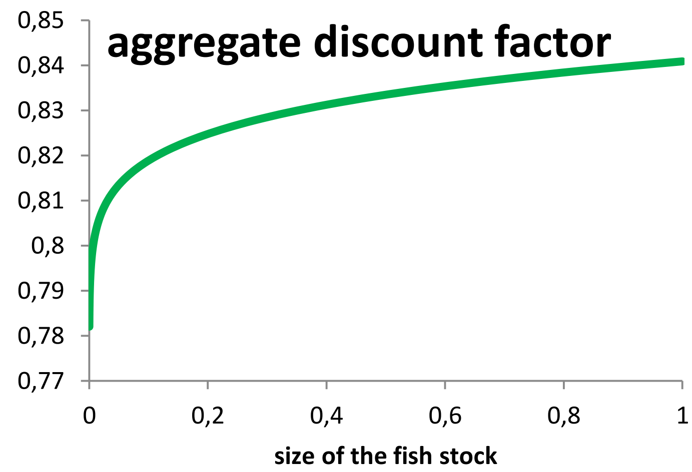
- Time consistent (by construction)
- The total harvest is inversely related to the average of bionomic factors, weighted by strategic weight
- Each player’s share is proportional to her strategic weight in the coalition
- The total quantity harvested is smaller than under competition (for any weight distribution)




Time consistency

- Maximizing the total payoff of the coalition over an infinite horizon in the space of open-loop strategies yields a time-inconsistent solution





Partial coordination with simultaneous moves

- Total harvest is directly related to the total of the bionomic rates of the outsiders, and inversely related to the weighted average of the bionomic factors of cooperating players
- Members of the coalition share their total catch in proportion of their strategic weights – outsider in proportion of their bionomic discount rate
- Total harvest is larger than under full cooperation, smaller than under competition

Partial coordination with first mover advantage

- Similar results – but with first-mover advantage, coalition members harvest more, outsider harvest less, and total harvest is higher than in the case of simultaneous moves

Coalition profitability and stability

Choice of Pareto-efficient weights

Coalition stability with two types of players

Comparing long-term welfare

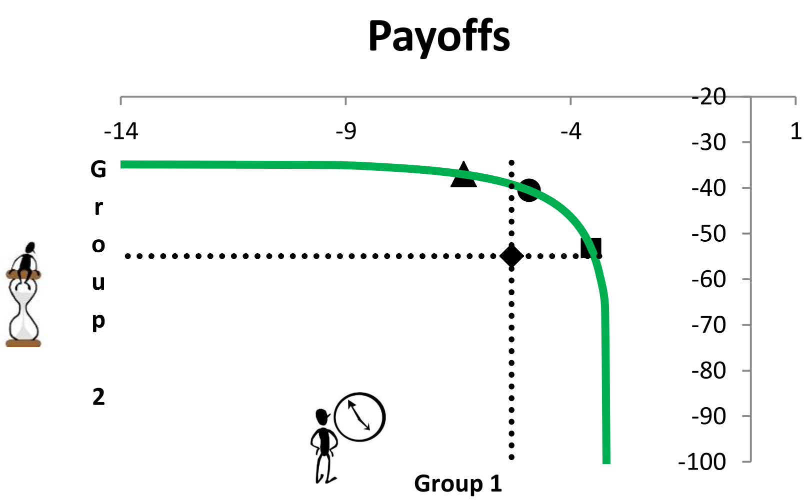
- Coalition profitability is independent of the resource level
- Condition highlights the trade-off between immediate consumption and investment in the resource

$$A_i^C + (1+\beta_i)\log s \geq A_i^N + (1+\beta_i)\log s$$

$$\log h_i^C + \beta_i \log q^C \geq \log h_i^N + \beta_i \log q^N$$

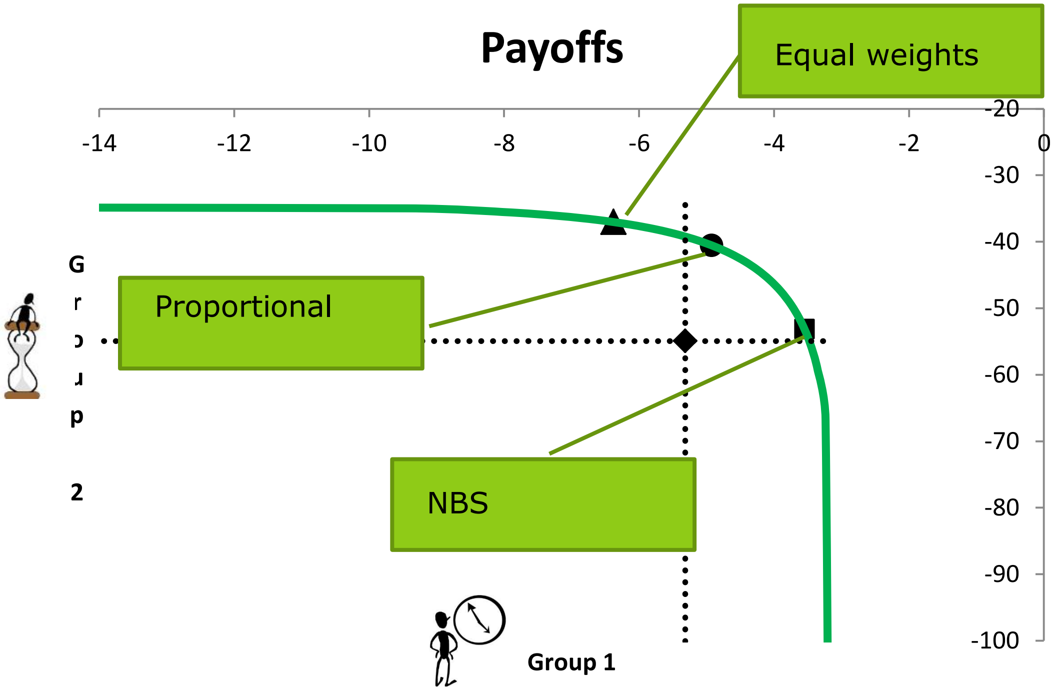
Pareto-efficient solutions

- There exist weight vectors such that profitability of the grand coalition is satisfied at all times
- If weights are the result of negotiation between the coalition members, patient players have inferior bargaining positions



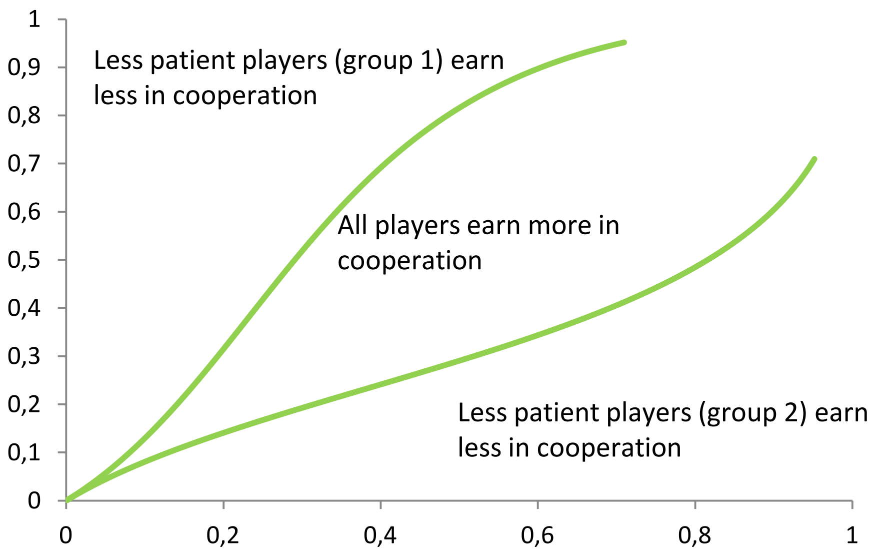
Pareto-efficient solutions

- In the context of coalition stability, we consider weights that do not depend on the composition of the coalition
  - Equal weights
  - Proportional to discount rate

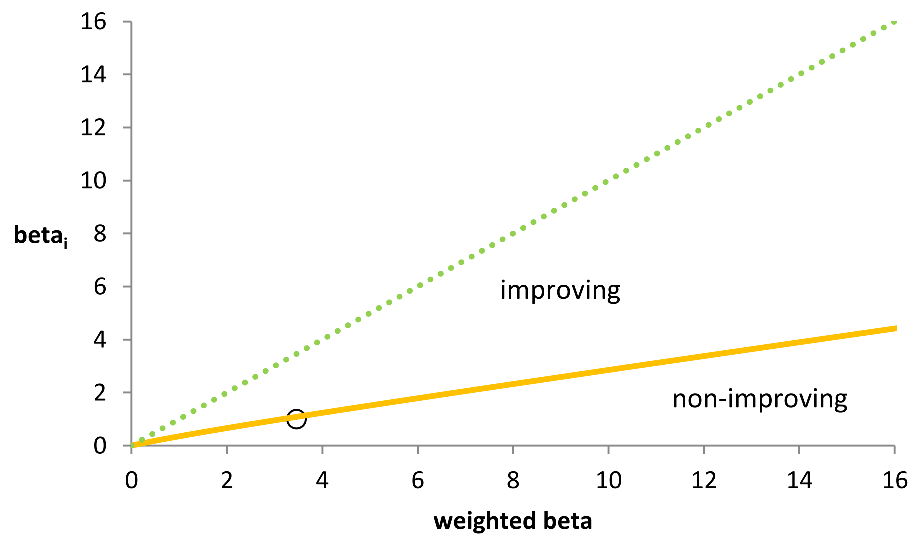


Profitability

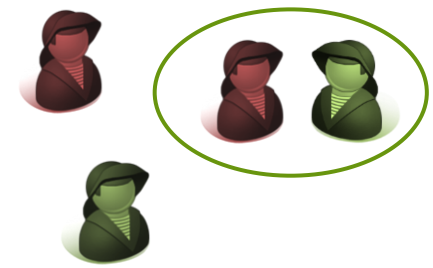
- Equal weights



- Proportional to dicount rate



Partial coordination

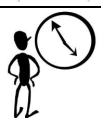


- Two types of players (characterized by discount rate and strategic weights
- Simultaneous moves: largest coalition is of size 2, for high values of the parameters
- Sequential moves: larger coalitions can form, with more reasonable values for the model parameters

Example

- Minimum parameter value ($\alpha\delta_1$) for the formation of coalitions, 8 players, $\alpha\delta_2$=0.95

Composition / Possible coalitions	(2,6)	(4,4)	(6,2)
(2,0)	0	0,8983	0,9231
(2,0)-(0,2)	0,8972	0,9228	0,9317
(2,0)-(0,2)-$(1,1)^{pr}$	0,9412	0,9425	0,9435
(2,0)-(0,2)-$(1,1)^{eq}$	0,9465	0,9468	0,9469



Summary and Conclusion

- Obtain time-consistent cooperative solution with heterogeneous time preferences
- Characterize Pareto-efficient sharing rules
- Obtain equilibrium strategies and study coalition stability for coalition vs. fringe model
- Asymmetry does not really help in solving the puzzle of small coalitions

Thank you