International fisheries agreements under slow and fast environmental changes

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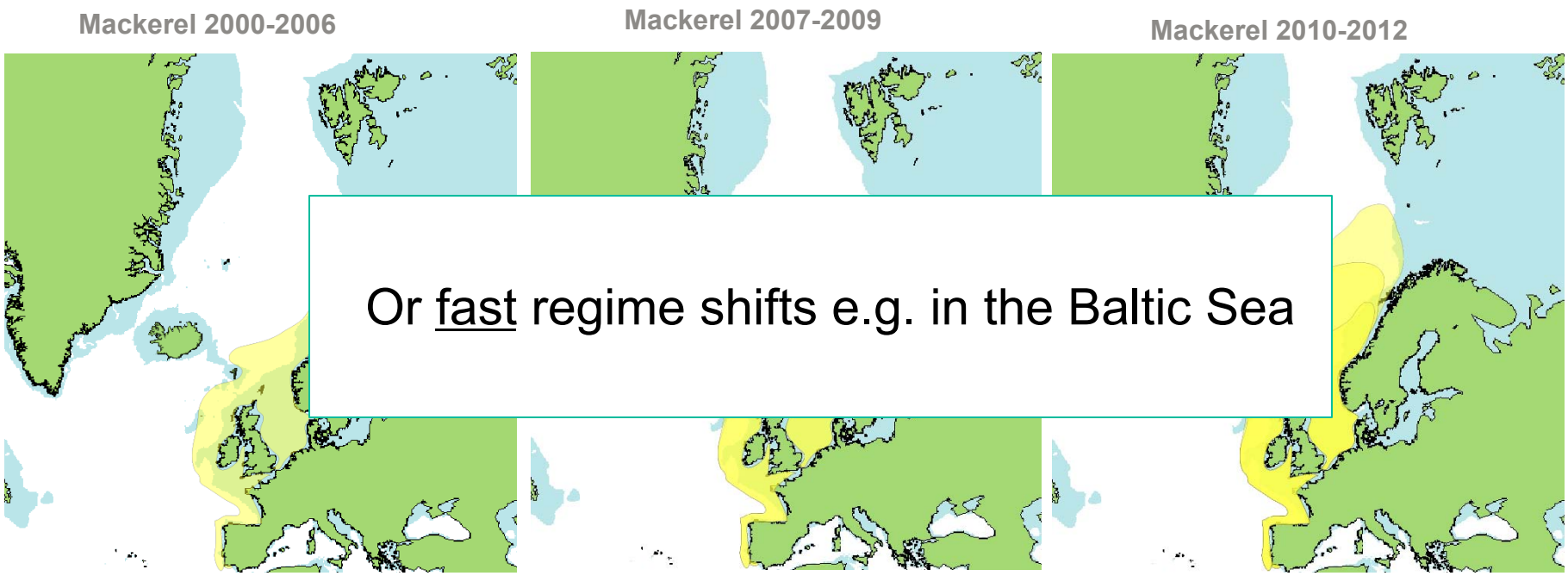
Study in a collaboration with Florian K. Diekert, University of Oslo

MOTIVATION OF THE STUDY

- Slow increase of Northeast Atlantic mackerel into Icelandic waters



Or fast regime shifts e.g. in the Baltic Sea

Source: Jan Arge Jacobsen, The Faroe Marine Research Institute.

RESEARCH QUESTIONS

- How does the speed at which stocks shift affect
  - Non-cooperative extraction?
  - Prospects of obtaining a binding contract?

FRAMEWORK

- Analytical study with two competing players
- First, Player A owns the whole resource
- At some point the whole resource will be owned by Player B

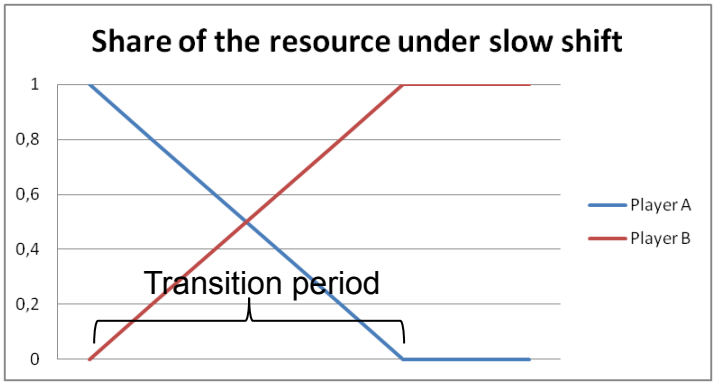
What happens in between?

SHIFT IN THE STOCK OWNERSHIP

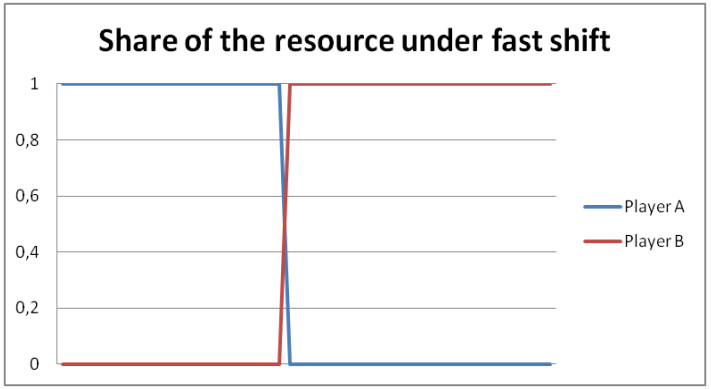
- In between there is either **slow** or **fast irreversible** shift in the ownership = **transition period**
- In the transition period we assume ***T* stages**
- A constant **probability *q*** that the **system stays in the current stage *τ***
- At a stage *τ* Player A owns a **share s_τ** and Player B owns a **share *1-* s_τ**
  - If the shares change, the system has moved to the next stage

SLOW AND FAST SHIFTS

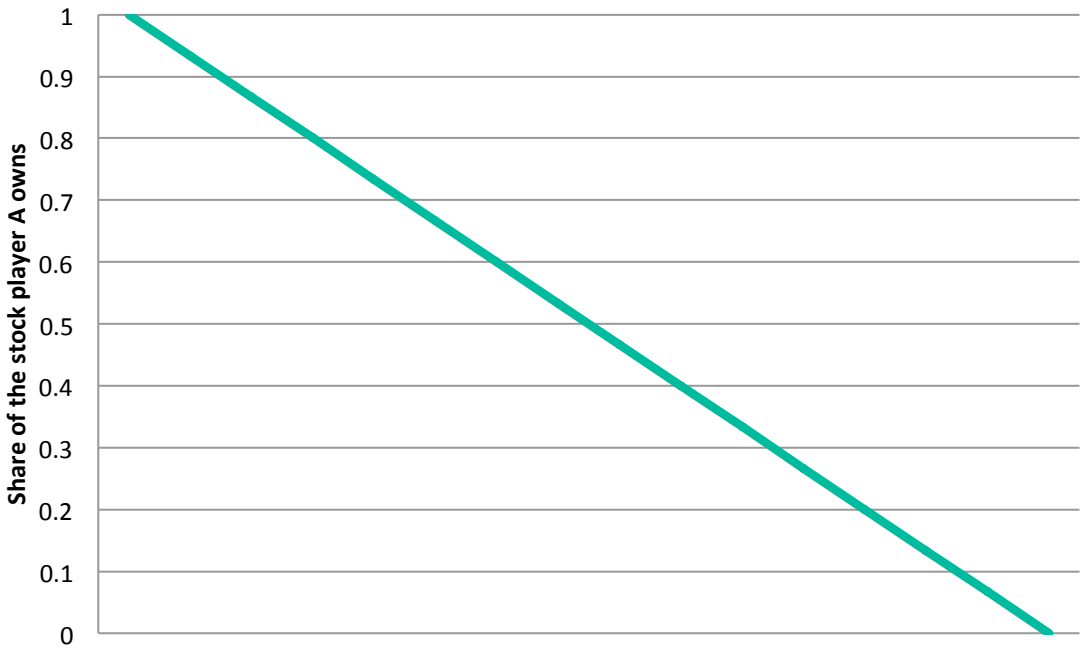
- **Slow shift**: At first, Player A owns a share $s_0 = 1$ and Player B a share $1 - s_0$ of the resource, but at each stage s_t decreases
  → Several stages
  → Finally Player B owns the whole resource and extracts optimally



- **Fast shift**: At first, Player A owns the whole resource but at some point, the whole resource shifts to Player B
  → Only two stages
  → Only one player harvesting at one time

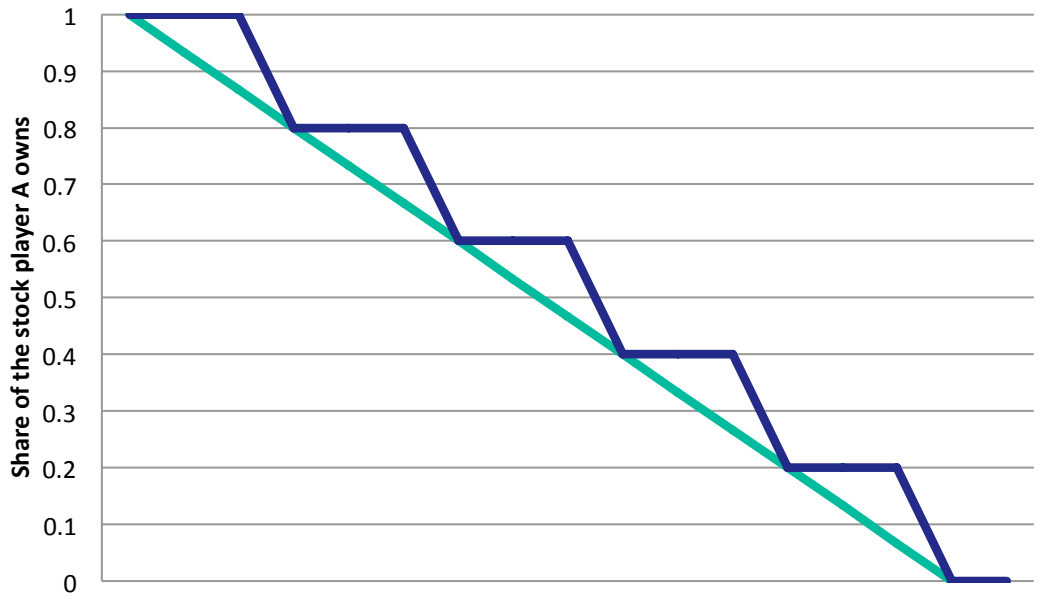


Smooth and gradual shift

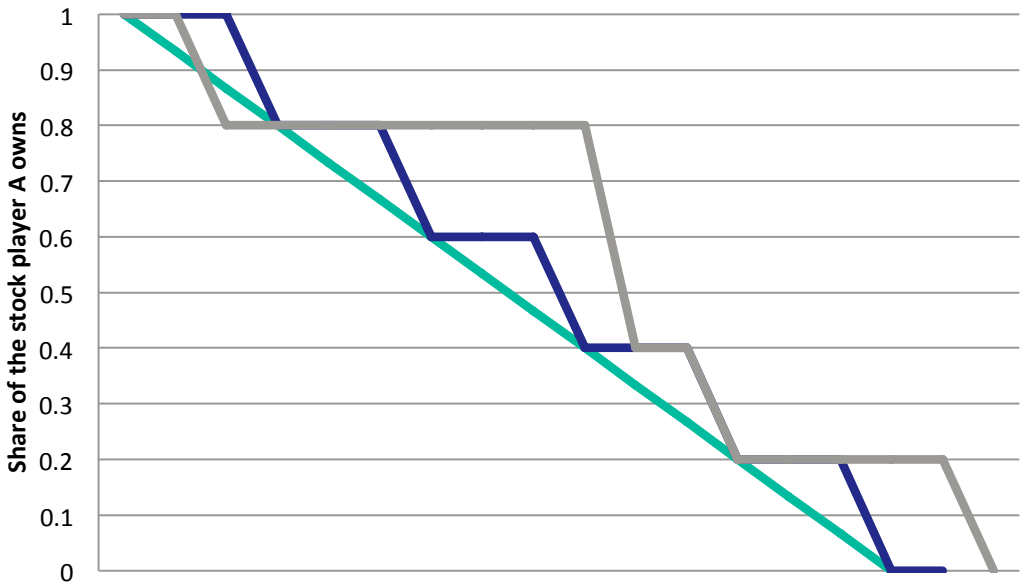


Large *T* and small *q*

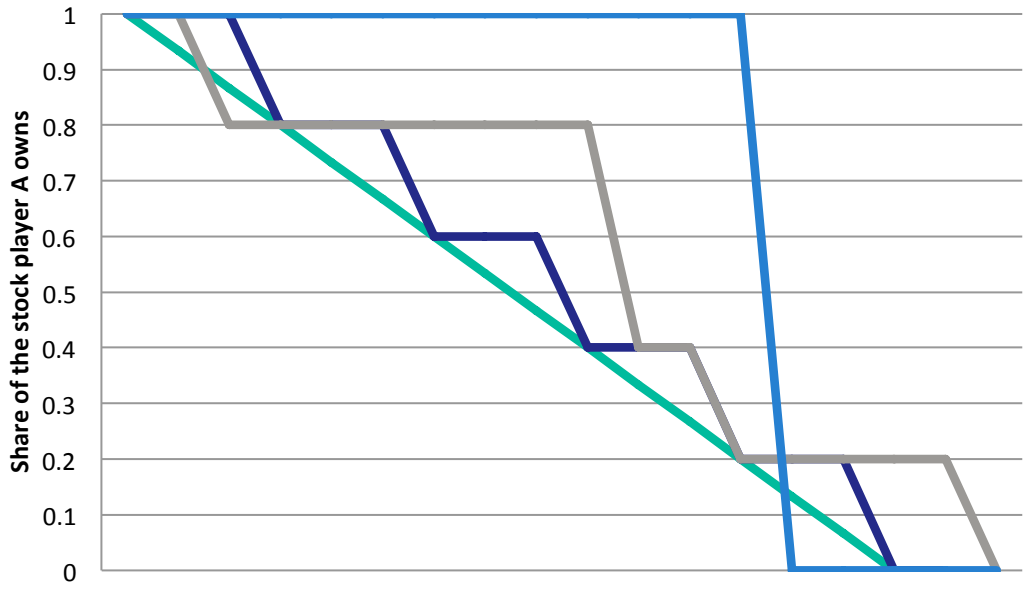
Longer stages



Even longer and uneven duration of stages



Only two stages = fast shift (regime shift)



***T*=2**

DYNAMIC PROGRAMMING MODEL

We use the classical fish-war model by Levhari & Mirman 1980

Social optimum:

Value function $V^*(x) = \max_{c \leq x} \{\ln c + \beta V^*((x-c)^\alpha)\}$

Optimal extraction rate $c^* = (1 - \alpha\beta)$

Benchmark Nash (no shift):

A's extraction rate $a^{nc} = \frac{1-\alpha\beta}{2-\alpha\beta}$

B's extraction rate $b^{nc} = \frac{1-\alpha\beta}{2-\alpha\beta}$

SOLUTION: THREE PHASES

PHASE I:

Interior solution for Player A, binding solution for Player B

Extraction rate for A:

$$a_\tau = s_\tau \gamma_\tau^A$$

Extraction rate for B:

$$b_\tau = 1 - s_\tau$$

PHASE II:

Interior solution for both players

Extraction rate for A:

$$a_\tau = \frac{\gamma_\tau^A(1-\gamma_\tau^B)}{1-\gamma_\tau^A\gamma_\tau^B}$$

Extraction rate for B:

$$b_\tau = \frac{\gamma_\tau^B(1-\gamma_\tau^A)}{1-\gamma_\tau^A\gamma_\tau^B}$$

PHASE III:

Binding solution for Player A, interior solution for Player B

Extraction rate for A:

$$a_\tau = s_\tau$$

Extraction rate for B:

$$b_\tau = (1-s_\tau)\gamma_\tau^B$$

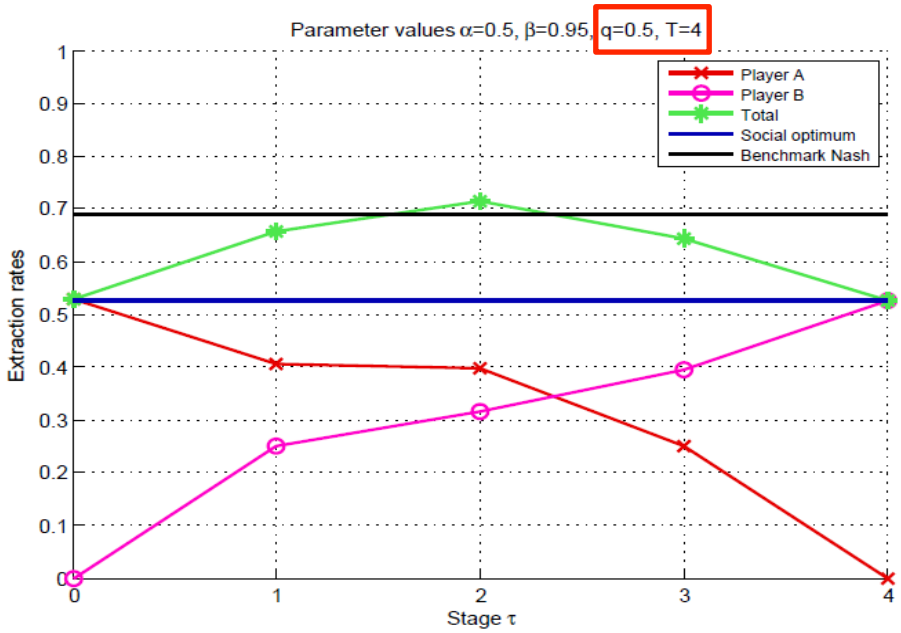
PROPOSITION

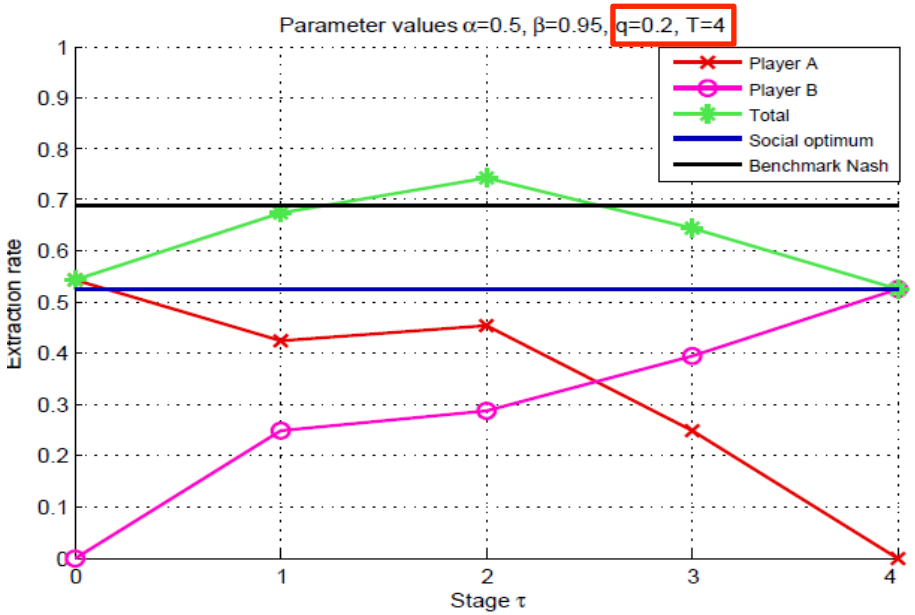
Proposition 1. *Changes in q and T affect the extraction rates in three different phases as follows:*

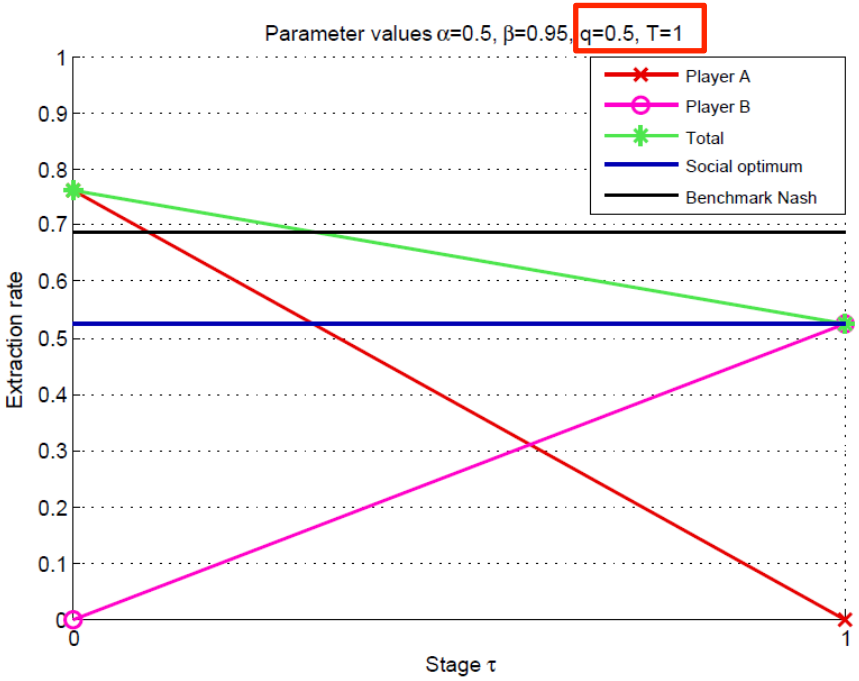
1. *In the first phase, an increase in q or T decreases A's extraction rate and total extraction rate, but has no effect on B's extraction rate as it is already harvesting according to its maximum share.*

2. *In the second phase, a higher q or T leads to a decrease in A's extraction rate and total extraction rate, but increases B's extraction rate.*

3. *In the third phase, q or T has no effect on either players' extraction rate nor the total extraction rate.*


Parameter values α=0.5, β=0.95, q=0.5, T=4
Player A
Player B
Total
Social optimum
Benchmark Nash
Extraction rates
Stage τ


Parameter values α=0.5, β=0.95, q=0.2, T=4
Player A
Player B
Total
Social optimum
Benchmark Nash
Extraction rate
Stage τ


Parameter values α=0.5, β=0.95, q=0.5, T=1
Player A
Player B
Total
Social optimum
Benchmark Nash
Extraction rate
Stage τ

CONCLUSIONS

- Low values for q and T result in even higher extraction rates, sometimes even exceeding the conventional Nash equilibrium
  - More difficult to attain a cooperative solution

- In other words: If the stock shifts very fast, it indicates difficulties in achieving a binding contract