The number of players in a fisheries game: curse or blessing?

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The Nash-Cournot Equilibrium

$$y_i = f\left(x_i, \overline{x}_{j \neq ì}\right) \qquad y_j = g\left(x_j, \overline{x}_{i \neq j}\right)$$

Equilibrium: mutually consistent expectations

$$\overline{x}_j = x_j^* \qquad \overline{x}_i = x_i^*$$

x_i^* maximizes f(.) for given x_j
x^*_j maximizes g(.) for given x_i

Optimal exploitation of a fish stock

Assume fixed price, constant unit cost of fish, *p* = net price

Discrete time model

$$X_{t+1} = S_t + G\left(S_t\right)$$

S = stock left after fishing

Maximize $$V = p\left(X_0 - S\right) + \frac{pG\left(S\right)}{r}$$

Solution given by $$G'\left(S^o\right) = r$$

Nash-Cournot equilibrium

Two players fish each in his own area

Player 1 always starts with a share *β* of *S*

After fishing stock grows as one unit, then migrates

Player 1 maximizes $V_1 = p\left(\beta X_0 - S_1\right) + \frac{p}{r}\left[\beta\left(S_1 + \bar{S}_2 + G\left(S_1 + \bar{S}_2\right)\right) - S_1\right]$

Solution given by $G'\left(S_1^* + \bar{S}_2\right) = -1 + \frac{1+r}{\beta}$ $\qquad G'\left(\bar{S}_1 + S_2^*\right) < -1 + \frac{1+r}{1-\beta}$

Mutually consistent expectations: $\bar{S}_i = S_i^*$

But RHS for 2 always > RHS for 1 unless *β* = 0.5

Player 2 would always want a smaller S than Player 1

So Player 2 leaves nothing behind

But Player 1 might leave nothing as well

Optimality condition for Player 1: $$\frac{dV_1}{dS_1} = p\left\{-1 + \frac{\beta\left[1 + G'\left(S_1\right)\right] - 1}{r}\right\} \le 0$$

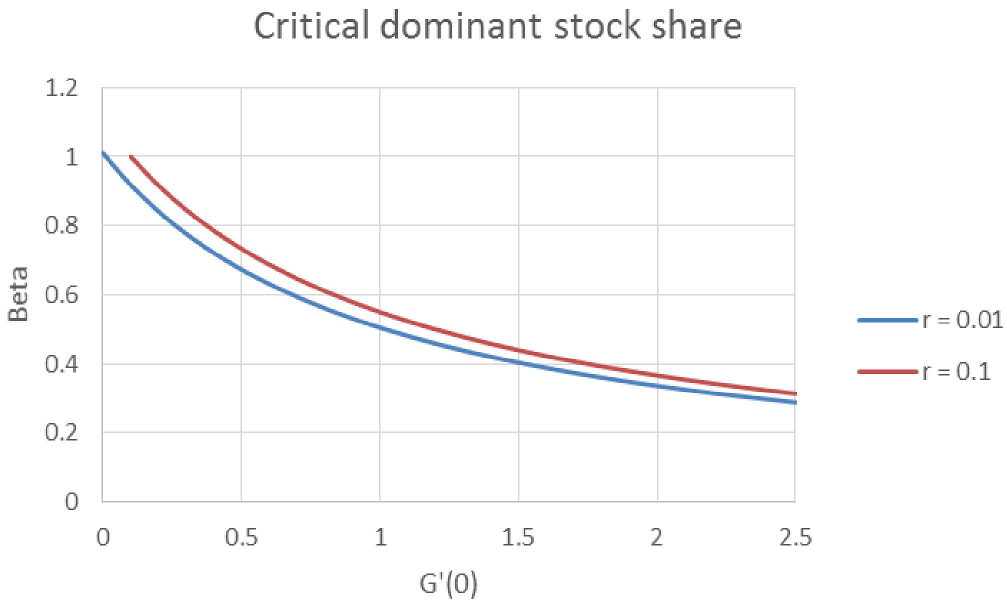
$$G'\left(S_1\right) \le -1 + \frac{1+r}{\beta}$$

If $G'\left(0\right) < -1 + \frac{1+r}{\beta}$ player 1 leaves nothing behind

For a viable population, we need opposite inequality, or

$$\beta > \frac{1+r}{1+G'\left(0\right)}$$

How critical β depends on G'(0)



Relatively insensitive to *r*

$\beta < 0.5$ implies more than two players

The zonal attachment principle

Each player should get a share in total cooperative quota (= cooperative profit when unit cost of fish independent of stock) equal to his share of stock

$1 - \alpha$ = minimum profit share of Player 2 to accept cooperative solution

Is $1 - \alpha = 1 - \beta$? (zonal attachment principle)

For minor player, is $1 – \alpha = 1 – \beta$ enough?

Participation constraint for Player 2:

$$(1-\alpha)\, pG\left(S^o\right) \geq p\left[(1-\beta)\left(S_1^* + G\left(S_1^*\right)\right)\right]$$

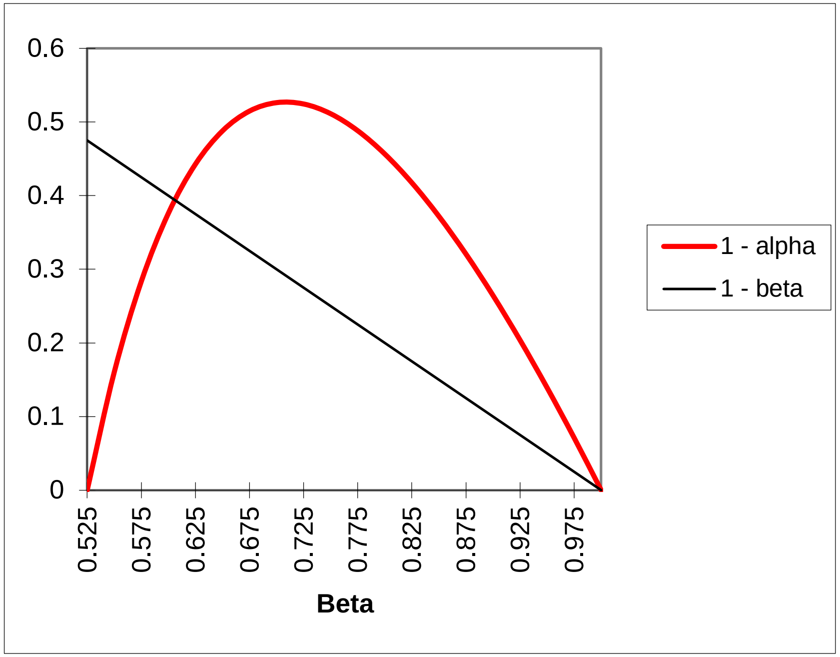
Player 2 leaves nothing behind in a non-cooperative solution

$$G'\left(S^o\right) = r,\, G'\left(S_1^*\right) = \frac{1-\beta+r}{\beta}, \Rightarrow S_1^* < S^o \Rightarrow G\left(S^o\right) > G\left(S_1^*\right)$$

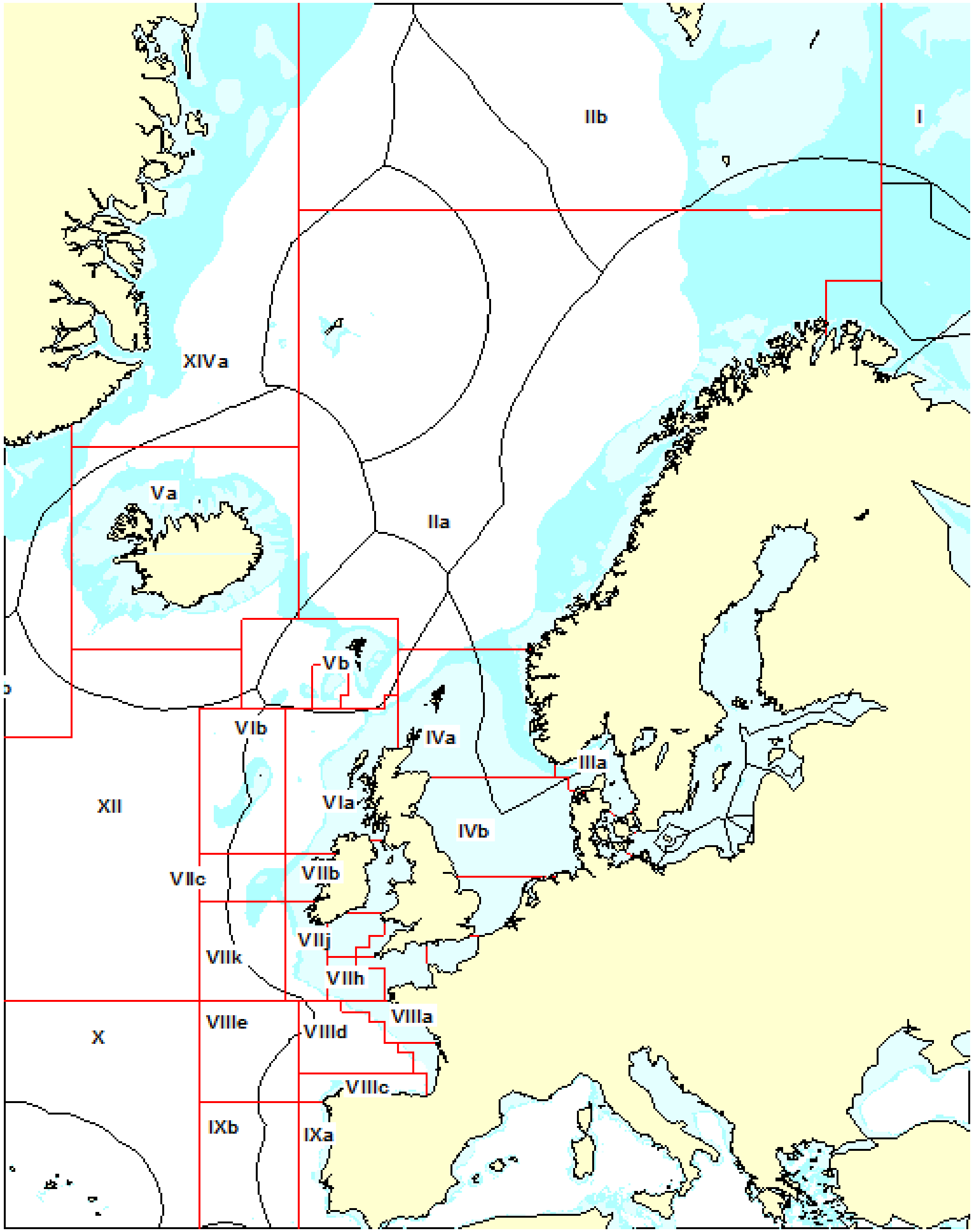
$$G\left(S^o\right) > S_1^* + G\left(S_1^*\right)?$$

Not necessarily

Illustration with $\beta > ½$, $a = 1$, $r = 0.05$

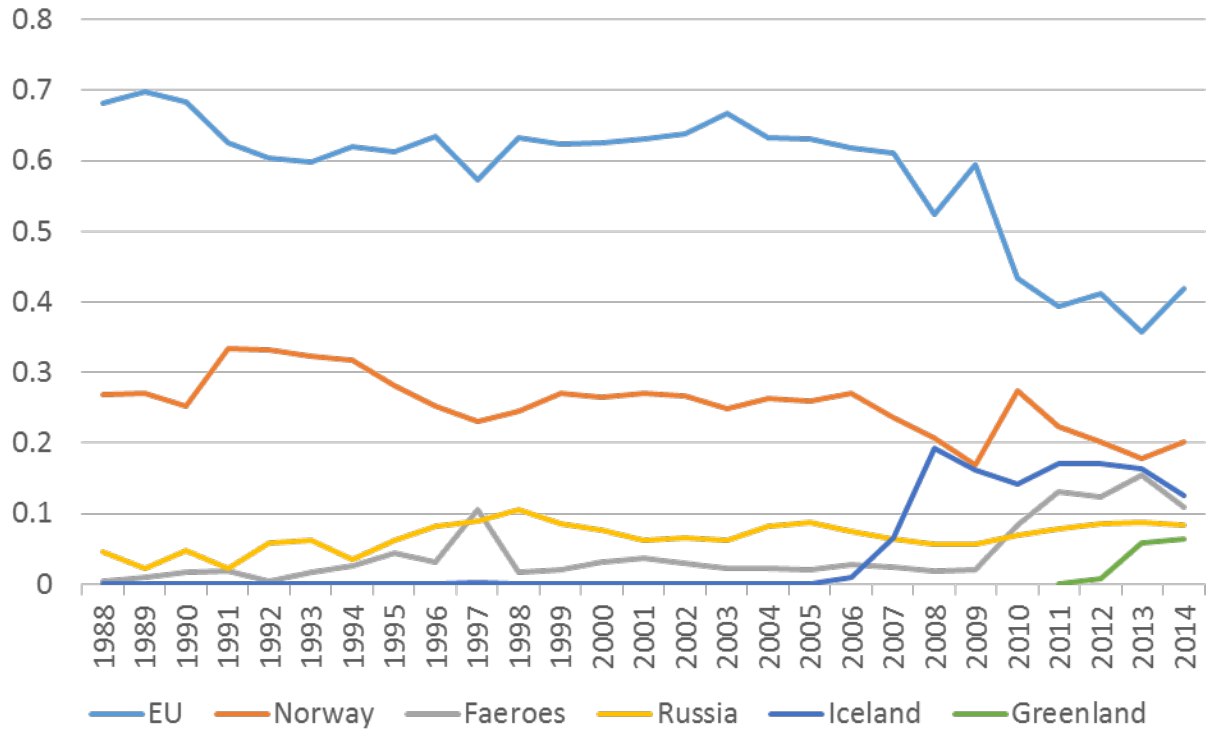


$1 - \alpha > 1 - \beta$ Player 2 must be offered a greater share of profits than his ”zonal attachment” in order to cooperate



Economic zones (EEZ) and ICES statistical areas in the NE Atlantic

Shares of mackerel catches



Agreement on management between EU, Norway, Faeroe Islands

Broke down 2009 after mackerel began to migrate to Iceland

Agreement 2015 between EU, Norway, Faeroe Islands

Iceland and Greenland still outside

Russia accommodated through NEAFC (an RFMO)

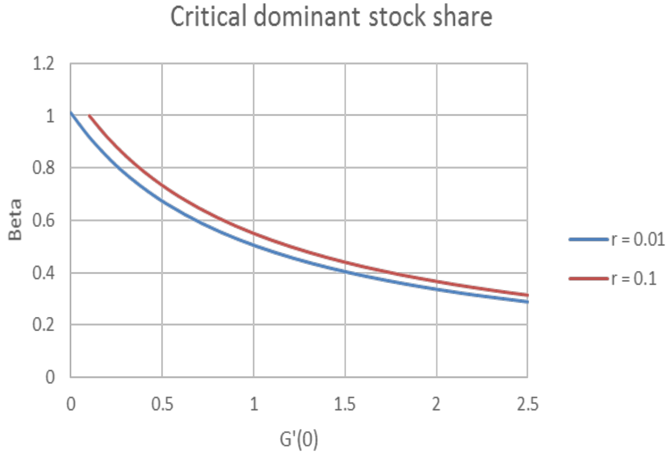
Countries seem preoccupied with total catch quota and its distribution

Fishing cost apparently not a consideration

Nash-Cournot equlibrium likely to mean total depletion

EU's share about 40%

Requires G'(0) > 1.5 for EU as sole stock protector



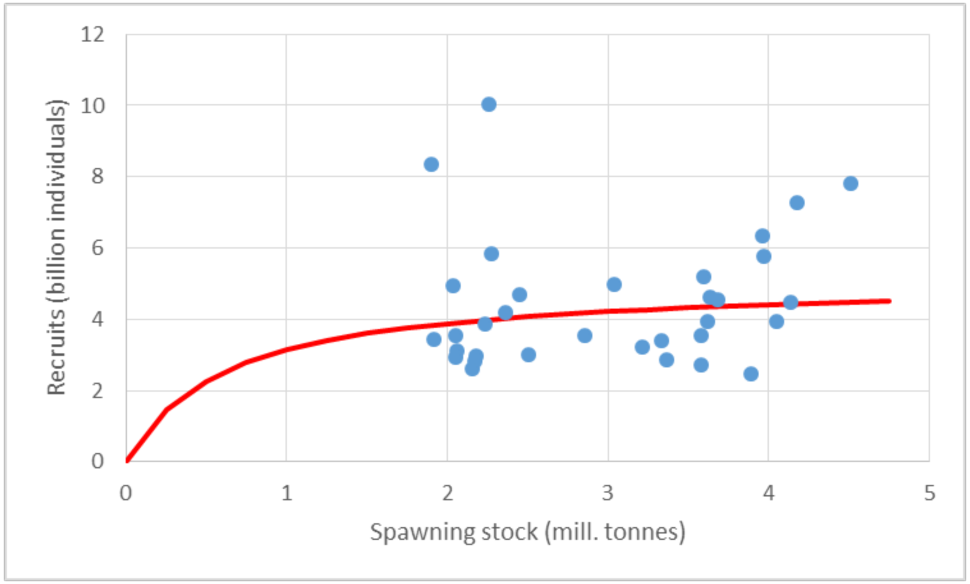
A Beverton-Holt model with no cost

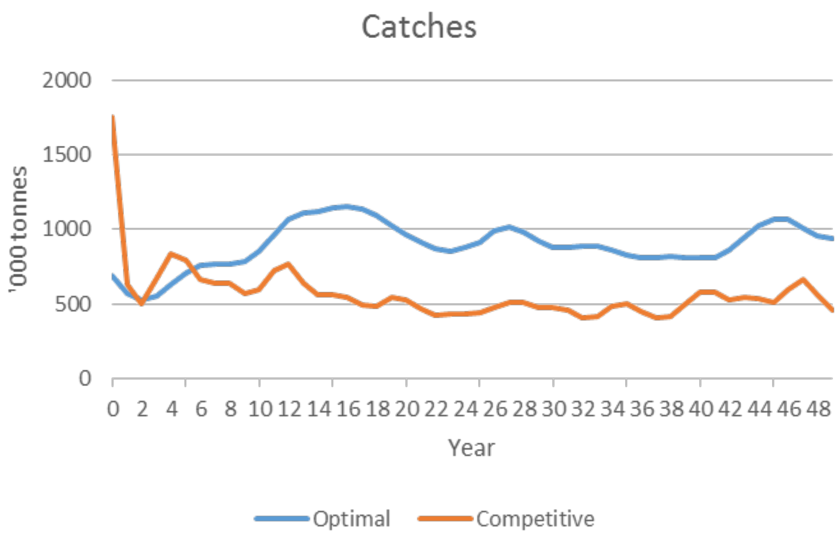
Players: EU, Norway, Faeroe Islands, Iceland, Russia

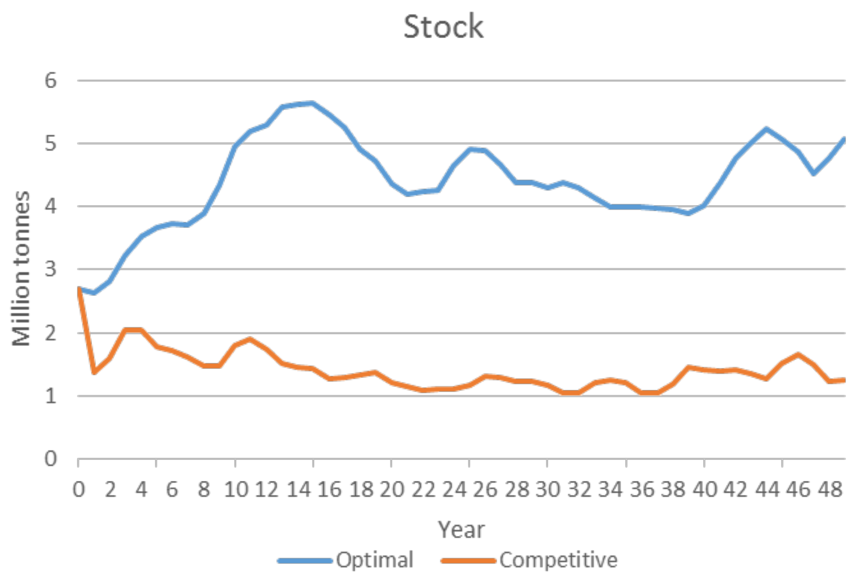
Maximize catch per year over 50 years

Maximum F = 2.0

Recruitment function with random variations



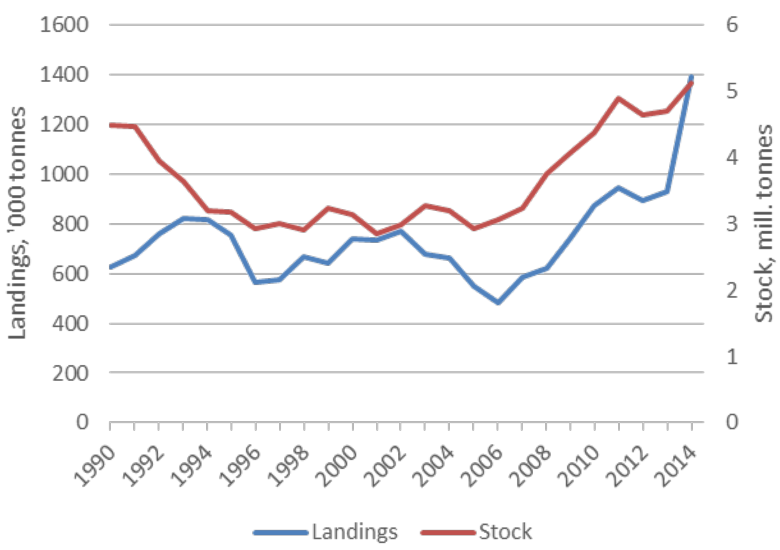


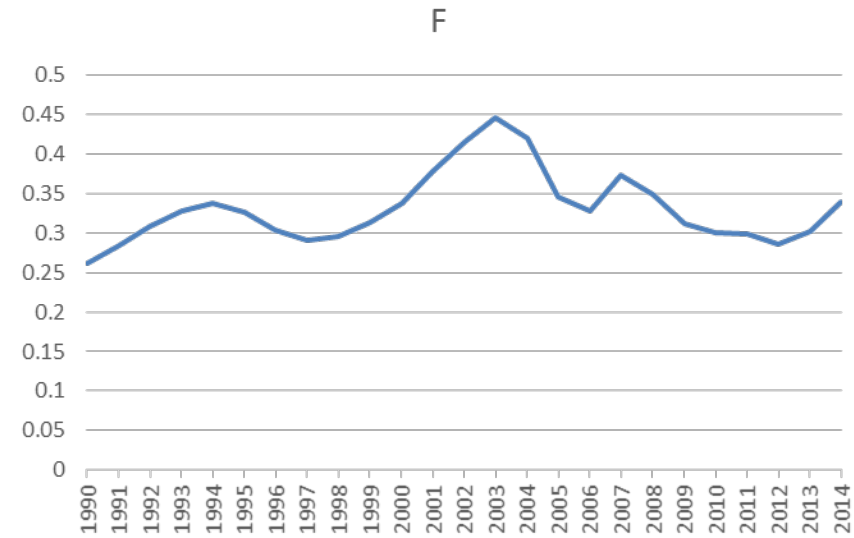


Nash-Cournot equilibrium results in much smaller catches and stock level than optimal

Total annihilation not possible because

- maxF << ∞
- Youngest age groups not fully selected





This is what reality looks like, despite no or only partial cooperation

Implicit cooperation because of fear of mutual annihilation otherwise?