Tecnological changes, market structure and harvest of a local pool resource

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1. Introduction

- FAO data clearly demonstrates the sad picture of most of the world's fish stocks:
  - Depletion
  - Overexploitation
  - Only a minor part is said to be in a healthy state

- Reasons (as we know):
  - Unregulation, unclear fishing rights, discards, criminal activities
  - Valuable fish stocks
  - Low harvesting costs, and efficient harvesting technology

- In this paper I take a closer look at the technology side. More efficent technology includes:
  - Larger end better equipped boats
  - Use of new synthetic materials
  - New finding techniques, etc.

- Why may more efficient technology and technological progress erode the profitability and sustainability of a fishery?

- Two main reasons:
  - The very nature of the biological growth process; natural growth is density dependent and typically peak-valued. For that reason; more efficient harvesting technology and more effort use (over a certain level) will for sure reduce the production; the catch

  - Institutional structure with unclear fishing rights, enforcement problems etc., will lead to too much fishing effort

- Here exploitation of an unregulated common property, or common pool, fishery stock is examined
  - Unregulated open-access (or no social norms… Ostrom 1990; common pool, myopic…Hardin 1968, Bromley 1991)
  - Local common; the number of fishermen is fixed (not open-access)

- Thinking about a small scale fishery in a develpment country context without any further regulations (but n fixed)

- Within this context I examine how more modern fishing technolgy, or improved fishing efficiency, may be a mixed bless not only for the fish abundance, but also for the rent generation of the fishermen

- Earlier studies (among others): Whitmarsh (1990), Murray (2007), Squires and Vestergaard (2013a, 2013b), Hannesson (2008)

- Contribution: Model exercise where the relationship between efficiency/new technology, market structure and profitability is examined

- Considering both search and schooling fishery

- Presentation:
  - 1) Harvesting model with a distinction between search fishery and schooling fishery
  - 2) Transitional dynamics and equilibrium search fishery
  - 3) The schooling fishery
  - 4) Summing up
  - …this is still work in progress…

2. Harvesting model

- Single fish stock exploited instantaneously and simultaneously by a fixed number of(identical) fishermen: $X_{t+1} = X_t + F(X_t) - nh_t$
- Harvest function: $h_t = qE_t X_t^{\beta}$
- *Search fishery (stock dependent costs):* $0 < \beta \le 1$
- Schooling fishery (*no stock dependent costs*):

  $\beta = 0$
- *q* is technology factor (disembodied, and given)

- Harvest costs: $C_t = (w / qX^{\beta})h_t = c(X_t, q)h_t$

  $C_t = (w / q)h_t = c(q)h_t$

- Higher value of *q* (lowering the harvest cost) represents more efficient technology

- Basic question: What is the effect of this parameter on stock exploitation, harvest and profitability of our fishery

- Fishing price sensitive to the amount of fish landed, and profit: $\pi_t = [a - b(h_t + h_t^{-1})]h_t - c(X_t, q)h_t$
- Myopic profit maximization; taking the stock as given (zero stock shadow price). Solved as a Nash-Cournot equilibrium for every year *t*

- Total catch: $H_t = nh_t = \dfrac{n[a - c(X_t, q)]}{(n+1)b}$

- Rent/profit: $\Pi_t = n\pi_t = \dfrac{n[a - c(X_t, q)]^2}{(n+1)^2 b} = \dfrac{bH_t^2}{n}$

- ***Result 1****: In the short-term more efficient technology increases the individual profit and the total rent*

  (well known (e.g., Anderson 1986) but included)

- But long-term: More efficient technology slows down the stock growth and reduces the equilibrium size of the fish stock and hence yields higher costs

- Two effects working in opposite directions (come back to this)

3. Transitional dynamics and steady state in the search fishery

- Dynamics: $$X_{t+1} = X_t + F(X_t) - \frac{n[a - c(X_t, q)]}{(n+1)b}$$
- Equilibrium: $$F(X^*) = \frac{n[a - c(X^*, q)]}{(n+1)b}$$
- Two possible equilibria under the present assumption of a standard logistic growth function

X

- High effort costs/and or low fishing efficiency (low and high natural growth)

Figure 1. Numerical example search fishery. Case i); single stable equilibrium characterized by high effort cost. Equilibria with high and low intrinsic natural growth rate

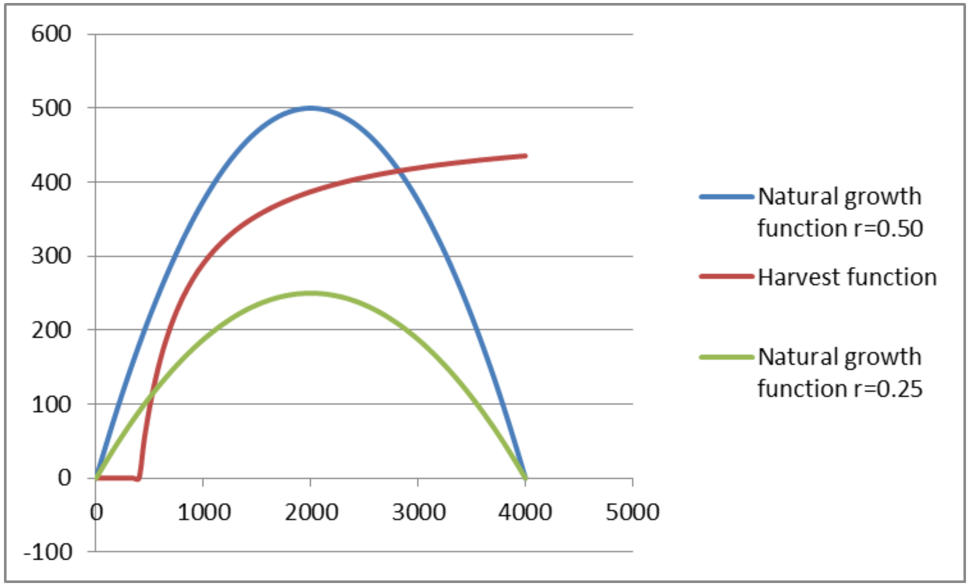

Figure note: Parameter values; $K = 4,000$ (tonnes), $r = 0.50$ and $r = 0.25$, $a = 3,000$ (Euro/tonn), $b = 2$ (Euro/tonn^2), $\beta = 1$, $n = 30$, $w = 20,000$ (Euro/vessel), $q = 0.05$ (1/vessel)

- Low effort costs/and or high fishing efficiency

Figure 2. Numerical example search fishery. Case ii); three equilibria characterized by low effort cost

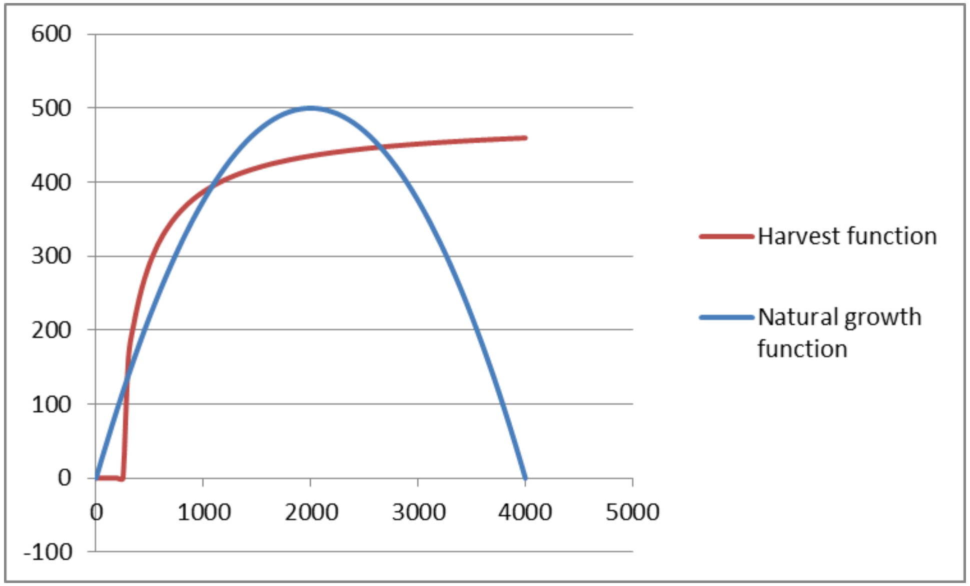

Figure note: Parameter values; $r = 0.50$ and $w = 10.000$ (Euro/vessel). Otherwise as in Figure 1

- Equilibrium condition: $F(X^*) = \frac{n[a - c(X^*, q)]}{(n+1)b}$

- The maximum possible harvest, the asymptote $\frac{na}{(n+1)b}$, vs the maximum sustainable yield $F(X^{msy})$

- **Result 2**: *In a search fishery with a fast growing fish stock, high carrying capacity and low fish price yields* $X^* > X^{msy}$*.*

- Does not hold irrespectively of the value of *q*. If infinite and costless fishing then extinction is a possibility

- The rent evaluated at equilibrium: $$\Pi^* = \frac{b(F(X^*)^2}{n}$$

- High exploitation pressure *X** low and equilibrium to the LHS of Xmsy. More efficient technology will reduce X* and F(X*), and hence the rent. And the opposite….

- ***Result 3****: More modern fishing technology has an ambiguous profitability effect in the search fishery in the long-term. With an initial high initial exploitation pressure, more efficient harvest technology dissipates the equilibrium rent. With an initial low exploitation pressure, more efficient technology increases the equilibrium rent*

- Therefore, while Result 1 indicates a positive short-run effect of more modern fishing technology, the long-term effect is ambiguous. Two counteracting forces:
  - direct positive effect (*Result 1*)
  - indirect negative effect working through lower stock

- *Result 3* contrasts the outcome of the standard sole owner model where more efficient echnology increases the equilibrium rent

- The equilibrium rent will be at its maximum when X*=Xmsy=K/2, and therefore:

$$\Pi^* = \frac{b(rK/4)^2}{n}$$

- The maximum rent related to biological factors, and the number of fishermen

- ***Result 4****: In the search fishery the maximum equilibrium rent is unrelated to fishing efficiency and costs*

- This is indeed a strange result as we in a social planner, sole owner setting find that lower costs *ceteris paribus* increases the rent

- But a certain value of technical efficiency coincides with this the maximum rent (but depends on all other parameters of the model)

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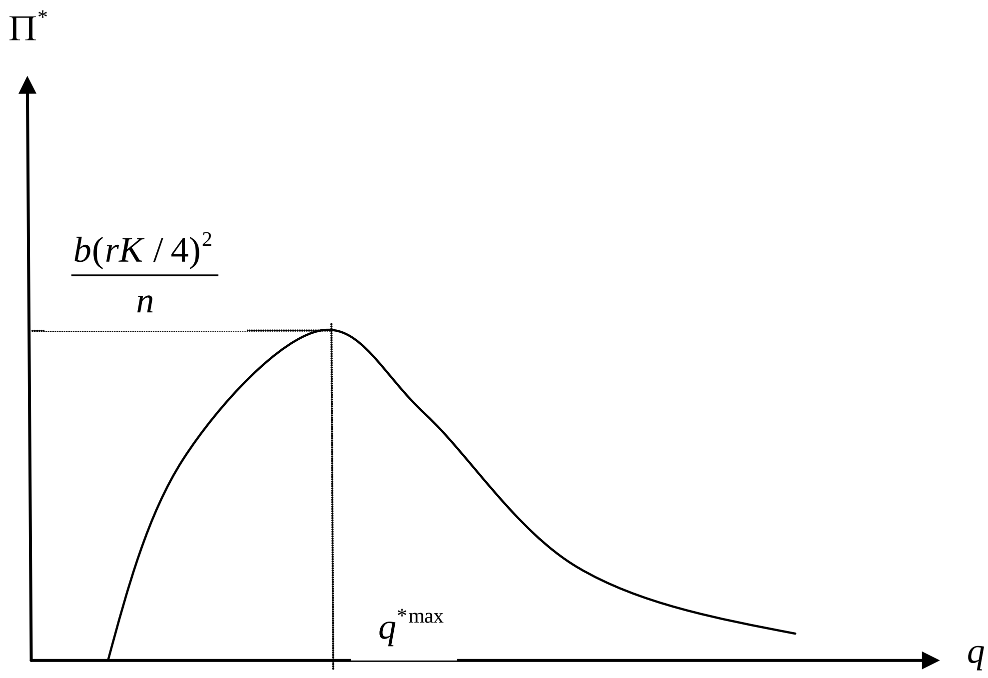
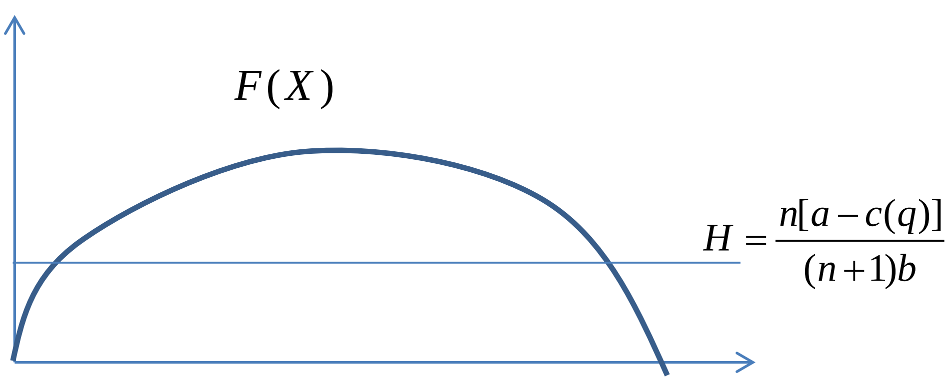


Π^*
$\frac{b(rK/4)^2}{n}$
$q^{*\max}$
q

4. The schooling fishery

- Harvest cost not related to the size of the stock. Stock equilibrium then $F(X^*) = \frac{n[a - c(q)]}{(n+1)b}$

- Yield two equilibria, or otherwise depletion of the stock. Stability…



- ***Result 5**: A schooling fish stock with low biological productivity and high market price exploited with efficient harvesting technology will for sure be depleted*
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- ***Result 6**: In the schooling fishery fishing technology has an unambiguous profitability effect under myopic exploitation. With a stable equilibrium and no depletion of the fish stock, more efficient technology up to a certain level increases the equilibrium rent*

5. Concluding remarks

- Studied a simple stylized model where a fish stock is myopic exploited by a fixed number of fishermen. Improved technology as ‘manna from heaven’ (Joan Robinson).
- Fish stock given (no shadow price), but interaction through the market price
- Solved as Nash-Cournot equilibrium
- Paper provides several results. Profitability effect of improved technological efficiency generally ambiguous
- Important distinction between search and schooling fishery