The role of technology in restoring fisheries – The tradegy of the commons squared

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Background.

- Many of the world's fisheries are in poor shape due to bad management
- It is well known that improved harvesting technology is a threat to fish stocks as harvest strategies in poorly regulated fisheries become more aggressive in order to satisfy the world's voracious demand for fish.
- *If* we can get our shit together and manage fish stocks properly, is improved technology good or bad for long term sustainability and ecological health?

Two views...

- Improved technology (or reduced input prices) makes it cheaper to produce a good. Therefore said good should be produced in larger quantities. Fish more!
- Improved technology makes a fishery more valuable and should therefore be managed more conservatively.
- Which view is right?

The canonical fisheries model

- Analysed in literally thousands of economic articles and books.
- Let h be the harvest rate and x be the stock. Let $\mathrm{d}x/\mathrm{d}t = G(x) - h$ and let instantanoeus profit be given by $D(h) - C(h)\alpha^{-1}$. α is a technology parameter
- Then an optimally managed fishery solves

$$\max_{h} \int_{0}^{\infty} \left(D\left(h\right) - C\left(h\right)\alpha^{-1}\right)e^{-\rho t}dt$$
$$s.t.: \dot{x} = G\left(x\right) - h,\ \ x\left(0\right) \text{ given}$$

First order conditions

$$\frac{\partial H}{\partial h} = D'\left(h\right) - C'\left(h\right)\alpha^{-1} - \mu \leq 0 \left(= 0 \text{ if } h > 0\right)$$
$$\dot{\mu} = \left(\rho - G'\left(x\right)\right)\mu$$

- First equation defines optimal $h = \phi\left(\mu, \alpha\right)$

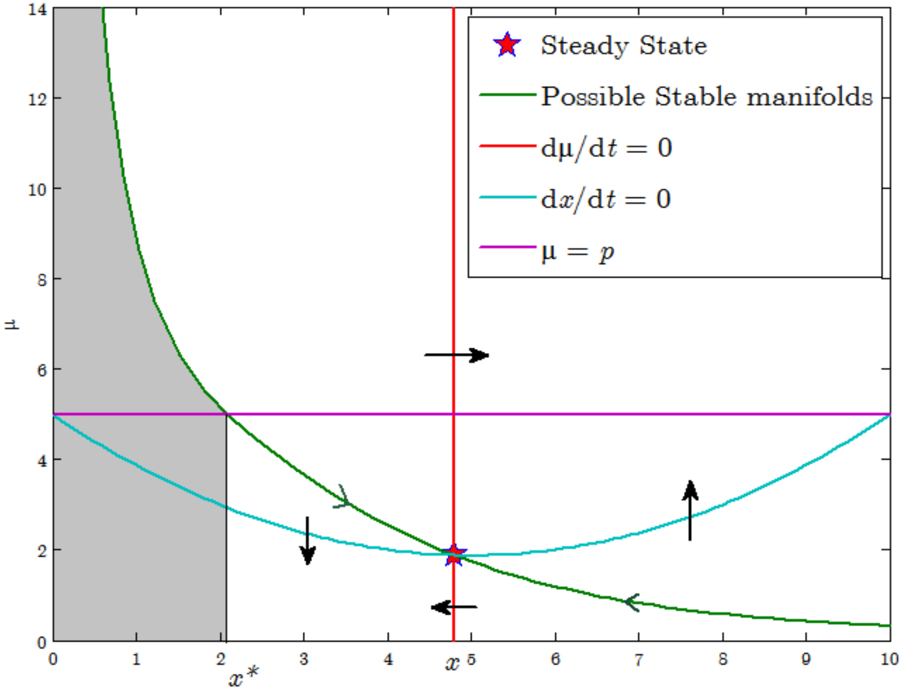
$$\frac{\partial h}{\partial \mu} \leq 0, \frac{\partial h}{\partial \alpha} \geq 0 \text{ and } \left(\frac{\partial \mu}{\partial \alpha}\right)_{h \text{ is constant}} = -\frac{\phi_a'}{\phi_\mu'} > 0 \text{ if defined}$$

- The second inequality indicates more harvest
- Together with the growth equation we can draw a phase diagram in (x, μ)-space

The solution in a phase diagram

$$D(h) = ph$$

$$C(h)\alpha^{-1} = \frac{c}{2\alpha}h^2$$



Things to note: The stable manifold is the derivative of the value function $\mu(x, \alpha)$. $h(\mu(x, \alpha), \alpha)$ is a feedback control.

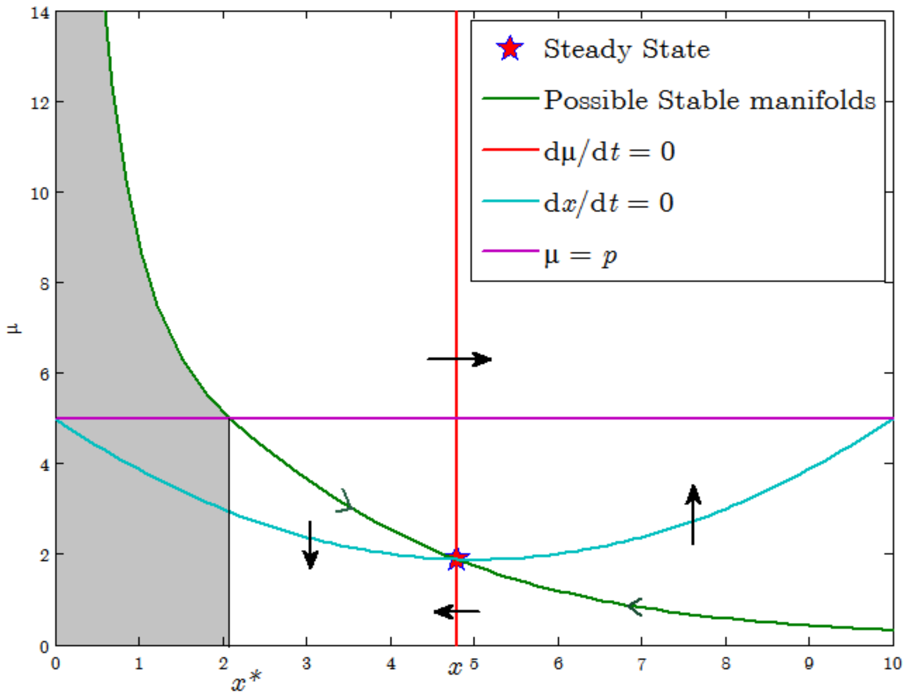
The shaded area is the value function

The analysis builds on two previous results

- As long as the intrinsic growth at stock equals zero is larger than the discount rate: the following *always* hold:
  - There is always some non-empty interval $A = [0, x^*]$ such that $h = 0$ for all x in A.
  - Given that $h = 0$ over some non-empty interval $[0, x^*]$, then the shadow price goes to infinity as x goes to zero
    - Nævdal and Skonhoft (2018).

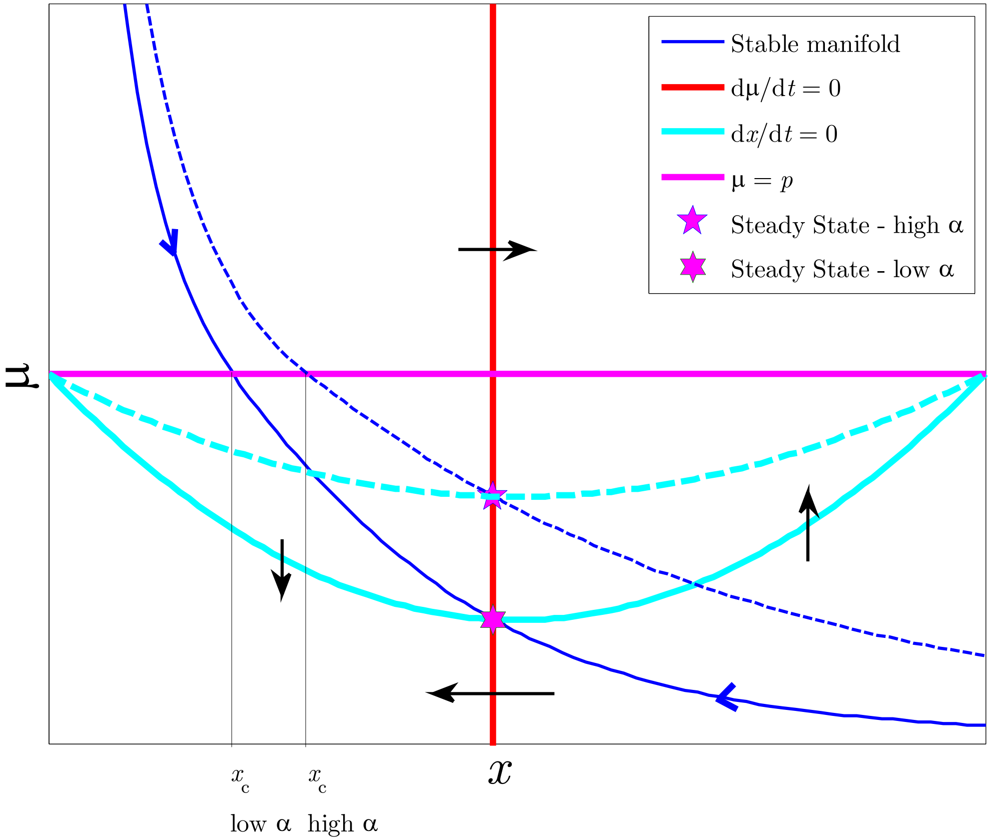
What this means...

- The x^* in the figure is always positive. Never fish when x is below x^*.



The first question we ask:

- What happens to x^* (from now on called x_c) when α increases?



Two things:

One isocline shifts upwards and all derivatives become steeper.

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Result 1:

- The lower the marginal cost, the higher must stock be before it is optimal to harvest.
- Using this one can prove Result 2.
- There is a critical stock level x' such that $x_c \leq x' \leq x$ in steady state where the more productive the harvesting technology, the lower is h.
- What I havn't been able to prove yet, but numerical experiments imply, is that x' = steady state x. That is certainly true in the limit as marginal harvest cost goes to zero.

Discussion

- In this model, technological cange encourages conservative harvest policies.
- The steady state is unchanged and below the steady state we harvest less.
- Intuitively: When productivity improves it is worth more to be in steady state. We therefore wants to get there faster and are willing to sacrifice current profits to achieve that. After all, the fish value grows faster in the ocean than the interest rate anyway.

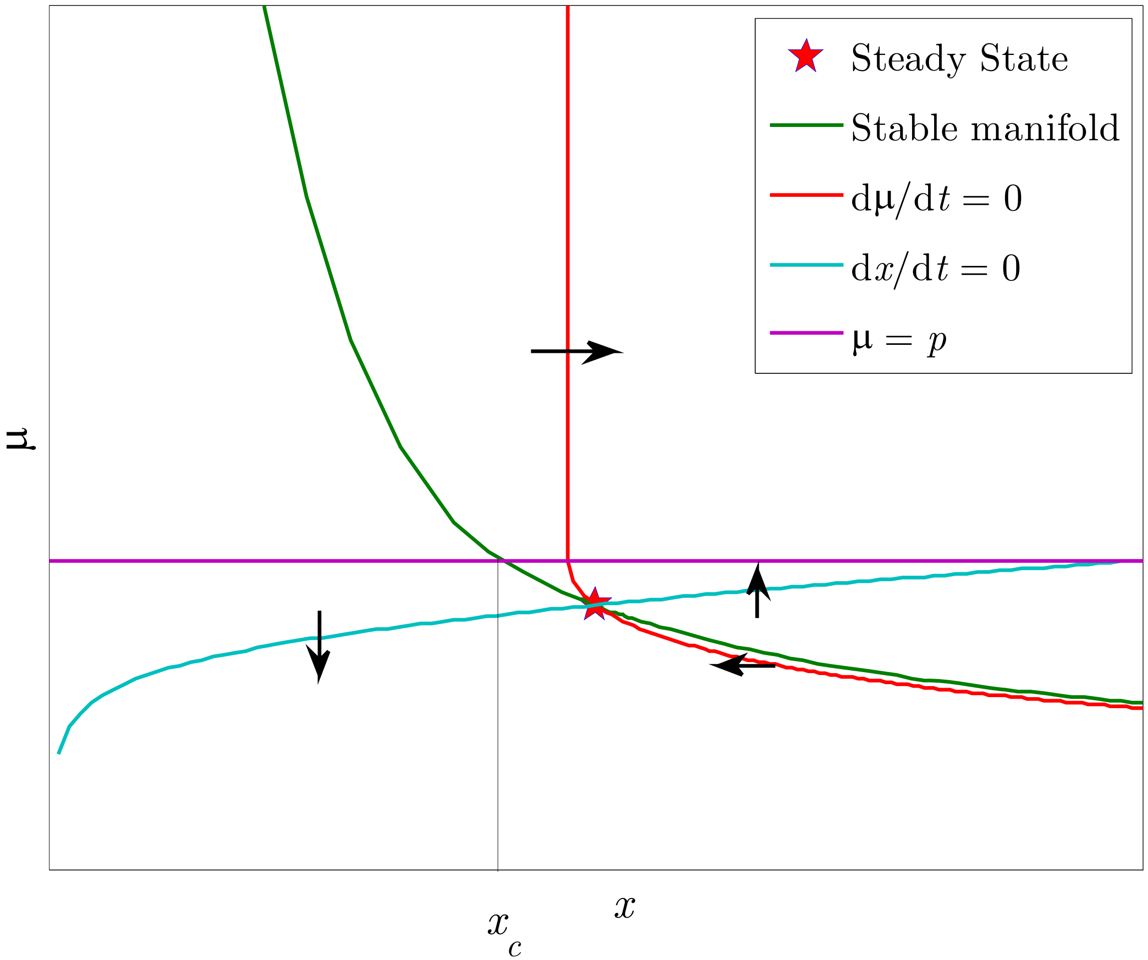
Adding density dependent costs

- We know that density dependent cost functions implies that higher productivity may imply lower steady state levels of fish stocks.
- Does this negate or dilute the results above?
- The model:

$$V\left(x\left(0\right),\alpha\right)=\max_{h\geq 0}\int_{0}^{\infty}\left(D\left(h\right)-C\left(h,x\right)\alpha^{-1}\right)e^{-\rho t}dt$$

subject to $\dot{x}=G\left(x\right)-h$ and $x\left(0\right)$ given.

The phase portait



A simple proposition

- x_c is an increasing function of α also when costs are density dependent.

- Proof based on the interpretation of the co-state variable as the derivative of the value function.
- The co-state $\mu(x, \alpha)$ tells us the value of one more fish in the lake. Clearly, a higher α implies a higher $\mu(x, \alpha)$.

That is enough to prove the following:

- μ as an increasing function of α implies that x_c is an increasing function of α.
- Implies that there is an interval over x where $h(x, \alpha)$ is a decreasing function of α.

- Again, higher productivity implies more conservative harvesting policies.

Policy implications for fisheries

- Wilen (2000) wrote a despairing piece bemoaning how little influence the fisheries literature has had on policy.
- However the notion and use of harvest control rules are spreading.
- Nævdal and Skonhoft (2019) argued that the existence of x_c implies that these rules are good approximations to theoretical optimal management.
- The results here should inform the how these rules are formulated

General Economic Insights

- The more productive we are the less should we produce. Somewhat counterintuitive?
- Underscores the importance of incorporating explicit dynamics into economic decision making.
- Gives me faith in the power of economic analysis.

Thank you for your patience