A tax on the catch in a steady-state fishery

A fishery is being exploited by a single owner. Total harvesting costs depend on both stock levels and harvesting rate in the following general form: $C(S(t), h(t))$, with $C_1 < 0, C_2 > 0$ and $C_{22} > 0$. The unit price of fish is constant and equal to p. The owner's discount rate is r. The fish stock varies with time according to the following differential equation: $\dot{S}(t) = G(S(t)) - h(t)$. The initial fish stock is S_0.

a) Solve for the owner's present value maximizing conditions in steady-state. *(Use the Maximum Principle in continuous time.)*

b) What happens when $r \to \infty$? Interpret.

c) Assume that the *social* discount rate is equal to $\rho < \infty$ and that $r = \infty$. How can a tax on the catch reestablish a socially optimal stock size?

d) Characterize the steady-state for an open access exploitation. Compare with your answer in b).

e) Characterize the tax rate that would reestablish optimality when the fishery is exploited under open access.

f) Assume now that $h(t) = eE(t)S(t)$, where E is effort and e is a parameter value related to technology. If the unit cost of effort is c, then total harvesting cost is now: $C(S(t), h(t)) = \frac{c}{eS}h = c(S)h$, with $c'(S) < 0$. How do your answers in b) and d) compare?

ANSWERS

a) We have the following problem:

$$\max_{h(t)} \int_0^\infty [ph(t) - C(S(t), h(t))]e^{-rt}dt \tag{1}$$

$$\dot{S}(t) = G(S(t)) - h(t) \tag{2}$$

$$S(0) = S_0 \tag{3}$$

The current-value Hamiltonian gives

$$H_C = ph(t) - C(S(t), h(t)) + \mu(t)[G(S(t)) - h(t)] \tag{4}$$

Which yields the following necessary conditions for a maximum:[1]

$$p - C_2(S, h) = \mu \tag{5}$$

$$\dot{\mu} - r\mu = -[C_1(S, h) + \mu G'(S)] \tag{6}$$

At the steady-state, we set $\dot{\mu} = 0$ and $h = G(S)$, to get

$$[p - C_2(S, G(S))]G'(S) - C_1(S, G(S)) = r[p - C_2(S, G(S))] \tag{7}$$

[1] We drop the time index to simplify the exposition.

or

$$\frac{\frac{\partial}{\partial S}[pG(S) - C(S, G(S))]}{p - C_2(S, G(S))} = r. \tag{8}$$

b) As a result, when $r \to \infty$, we have

$$p = C_2(S, G(S)). \tag{9}$$

Note that $C_2(S, G(S)) = \frac{\partial}{\partial h}C(S, h)$ with $h = G(S)$ in the steady-state. Intuitively, a myopic exclusive owner will equate marginal revenue to the marginal cost of harvesting, where the latter does not include the effect of today's harvest rate on future stock levels (the user cost). The marginal rent is dissipated much like in the standard problem of a firm whose decisions are not inter-temporally linked.

c)
Efficiency dictates that (see expression 5):

$$C_2(S, h) = p - \mu, \tag{10}$$

where μ denotes the user cost of the resource. Assuming that μ can be estimated, one simply has to choose a tax rate t per unit catch such that $t = \mu$ in order to re-establish social efficiency.

d)
The case of free access is quite different. It says that when the number of fishers is arbitrarily large, total rents are completely dissipated (Dasgupta and Heal 1979). This is true at every period (Brooks, Murray, Salant and Weise 1999). Hence, we have, in the steady-state,

$$\frac{C(S, G(S))}{G(S)} = p. \tag{11}$$

This is not the same condition as condition (9) in general and, more importantly, it conveys a very different economic message.

The myopic owner is inefficient for one reason only, which is that he acts as if the resource were not constrained by its reproduction rate, i.e. as if it were infinite in quantity. That leads him to exhaust the *marginal* rent.

Open access fishers similarly act myopically, but they also do not account for crowding externalities. This leads them to exhaust the *total* rents.

e)
One must find a proper tax rate per unit of harvest t, for which

$$\frac{C(S, h^*)}{h^*} = p - t, \tag{12}$$

in which case the efficient harvesting level h^* is reached.

f) In the Shaefer (1957) model, the two equilibria are equivalent because crowding externalities are absent. Indeed, when $C(S,h) = c(S)h$, we get $\frac{C(S,h)}{h} = \frac{\partial}{\partial h}C(S,h) = c(S)$. This is a very special case which has led many to suggest that when a single-owner fishery optimizes using an infinite discount rate, he will choose the same steady-state harvest rate as the open access fishery. As shown above, this conclusion is generally wrong.