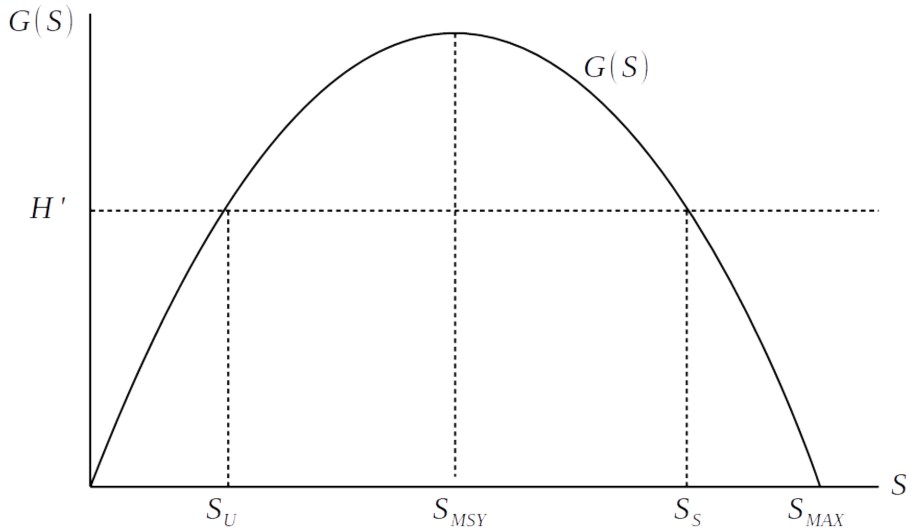
ECN 275/375: Renewables (fisheries and forests)

(EX6-1) Fisheries

This exercise deals with the tradeoff between avoiding extinction of a fish species and treating fish stocks as a capital asset under varying degrees of uncertainty about the stock size or the growth function.

(a) Draw a standard stock-growth function $G(S)$ of stocks S diagram. Insert a harvest level, H', such that we get two equilibria, a stable $\{H', S_S\}$ and an unstable $\{H', S_U\}$ equilibrium.

Answer: See figure below.



(b) Suppose that H' is the steady state (long run) harvest level that maximizes economic rents (profits) from this fishery. Explain why under full certainty about the stock size, S, and the growth function $G(S)$, it is profitable to seek to gradually adjust the fishery to the unstable equilibrium, $\{H', S_U\}$.

Answer: Suppose the stock size is S_S. By fishing the fish stock $\Delta S = S_S - S_U$, the owner of the fishery (it could be a government) could deposit the net revenues from this extra catch, $P\Delta S$ where P is the net price, and earn the capital income $rP\Delta S$. r is the interest rate on this deposit.

(c) What is the size of the discount rate? Explain why.

Answer: Indifference between letting fish grow in the ocean or the profits from harvesting the fish earn interest in a capital market at the rate r should equal the growth rate of the fish stock, i.e., $r = G'(S_U)$. If this was not the case, rents could be increased by adjusting the stock level to S_U: equal capital gains from money deposited in the bank and the capital asset fish stock in the sea.

Now move to a situation that is more relevant for real life fisheries management. To keep things as simple as possible, we assume the fish lives for one year when it is mature for harvest after spawning (not so realistic as the quality of the fish is much higher before spawning, but not to complicate matters :-)). Suppose this is a virgin fishery, i.e., we start fishing on a newly detected fish species.

(d) At the start of the fishery for this species, we know little about the growth function, $G(S)$. Explain the learning process as the fishery proceeds. Hint: use the change in the stock and the stability properties of the equilibria to learn about the growth function

OR think in terms of the steady state economically optimal harvest $H^{\delta=r}(S)$.

Answer: As this is a virgin fishery, we start fishing at S_{MAX} where the net growth is zero. As we gradually increase harvest levels (with some years in between without increases in the harvest, i.e., harvest is constant), we will reduce the fish stock. As long as we have $S_t > S_{MSY}$, we would be in a stable equilibrium, and stocks would rebound. Eventually, gradual harvest increases would lead us to a situation where $H_t > G'(S_t)$ and we would not be able to maintain our the harvest level. This is a signal that $S_t < S_{MSY}$, and that there are good reasons to reduce harvests as we have no knowledge of the shape of the growth function for $S_t < S_{MSY}$ (we have not been there yet).

The steady state economically optimal harvest $H^{\delta=r}(S^*)$ emerges in the same way. As above note you may need to have temporary harvests above H_{MSY} to get to stock sizes $S_t < S^{MSY}$ where $\delta = G'(S_t) > 0$ before harvests are reduced to $H^{\delta=r}(S^*)$. Note that dropped time subscript indicates a steady state.

(e) What are the implications of what we have learned for fisheries management under uncertainty?

Answer: For this fishery with a short (one year turnaround for the fish), it may be very risky to move into $S_t < S_{MSY}$ as we now have unknown unstable equilibria ahead. Without yearly fluctuations in the growth function the solution in (d) $H^{\delta=r}(S^*)$ works when we have good knowledge about the species.

With downside fluctuations in the growth rate, we should seek a harvest level $H_{SMS} < H^{\delta=r}(S^*)$ to reduce chances of "overfishing" and hence reducing stock sises below S^* which would render our steady state solution in (d) obsolete.

Note that $H_{SMS} < H^{\delta=r}(S^*)$ comes at a cost equal to the lost profits from reducing harvests from the the steady state to the SMS harvest: . $(P_t H^{\delta=r}(S^*) - C(H^{\delta=r})) - ((P_t H_{SMS}) - C(H_{HMS}))$.

(EX6-2) The single rotation period even aged stand forest model

Lecture note 17 expressed the single rotation period even aged stand profit maximization problem as follows: maximize the rents from timber harvest, choosing the rotation age, *T*, of the stand:

$$\begin{Bmatrix} MAX \\ T \end{Bmatrix} \pi(T) = \begin{Bmatrix} MAX \\ T \end{Bmatrix} \left(pS_T e^{-rT} - k \right)$$

where: $p = (P - C)$ is the net price, S_T is the standing timber volume at the time of harvest, and k is replanting costs at the beginning of the rotation.

(a) Rewrite the profit maximization problem when thinning occurs at time $\tau < T$.

Answer: $\begin{Bmatrix} MAX \\ T \end{Bmatrix} \pi(T) = \begin{Bmatrix} MAX \\ T \end{Bmatrix} \left(pS_T e^{-rT} + \pi_\tau e^{-r\tau} - k \right)$ (π_τ are profits from thinning).

(b) Assuming that thinning does not affect $\dot{S}_T$ and S_T : (i) how does thinning influence the optimal rotation age? (ii) What is the condition for thinning to be profitable?

Answer: No impact as $\dot{S}_T$ and S_T remain unchanged and the term $\pi_\tau e^{-r\tau}$ is a constant, i.e., it disappears when differentiating the objective function to find the FOC. Hence, $\dot{S}_T / S_T = i$ is unchanged.

(ii) As thinning does not affect $\dot{S}_T$ and S_T, the only way thinning can be profitable is if $\pi_\tau > 0$.

(c) Now, suppose that thinning increases $\dot{S}_T$. How will that affect the optimal rotation age?

Answer: This implies that $\dot{S}/S$ shifts up, which implies that $\dot{S}_T/S_T = i$ takes place at *T'* > *T*, i.e., the optimal rotation age increases.

Remark: increased growth over time is not surprising as the remaining trees get more light and grows faster.

(EX6-3) Multiple use forest management

What is the impact of the non-timber benefits from moose hunting on the optimal rotation age under single and multiple rotations? When explaining your answer, emphasize the difference between the single and multiple rotation cases.

Answer: The main benefits from moose hunting occur early in the rotation period (the bullets are not needed for a complete answer, but they underscore the importance of the biological links):

- Just after clear cutting, the growing conditions improve strongly for important moose diet plants like herbs and leaved trees like salix (selje), birch (bjørk), cranberry (rogn) and aspen (osp). Availability of suitable edible plants for the moose are among the most limiting factors for a larger and healthy moose population
- There is little moose feed in a mature and dense spruce stand, but it still provides cover.

This gives rise to the last figure in lecture note 17. Assuming that this figure captures the main patterns of the tree stand age profile, there the moose hunting benefits do not affect total benefits in a mature stand.

Under a single rotation period model, the optimal rotation age is therefore remains the same.

Under multiple rotation periods, the large benefits from moose hunting early in the rotation increase overall benefits. This lowers the optimal rotation age compared to the single period model, as a shorter rotation age allows for these benefits to exist for a larger share of the time span in multiple rotations.

Remark: for benefits occurring late in a tree stand's rotation this changes (the $\dot{S}/S$ curve crosses the interest rate line at a higher rotation age.