ECN 275/375 – Natural resource and environmental economics
12:15-15:15 April 10, 2025

All help aids allowed except assistance from others.
This test consists of 3 questions, for a total score of 100 points.
All questions are to be answered. You may answer in English or Norwegian.

In the case that you find a question unclear, or you are uncertain about what is meant, state the extra assumptions you need to be able to answer the question.

This test has been designed to limit the benefits of using Chat GPT and similar artificial intelligence tools. If AI use is detected beyond reasonable doubt, unreported use leads to a score of zero. Students can use AI tools if they self-report such use at a cost: A question with self-reported AI use reduces the score by 40%.

When I submit my answers on this test, I confirm that I have worked alone on my answers and not cooperated with others. I am aware that cooperation with others is to be considered an attempt or a contribution to cheat.
I am aware of the consequences of cheating, cfr. academic regulations for NMBU.

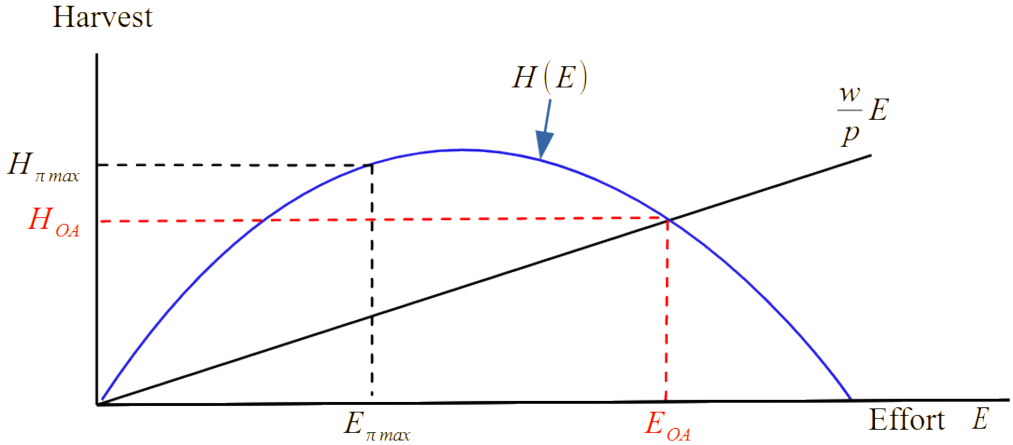
Your name: NN (+ ECN 275 or ECN 375)

Question 1 (30 points – 10 points for each sub-question a-c)

An open access fishery as illustrated below has the following solutions:

- the profit maximizing effort level: $E_{\pi\,max}$
- the open access effort level: E_{OA}

when $\frac{w}{p}$ is the real wage.



(a) Write down the profit function of this fishery and solve for the profit maximizing and show the condition for open access effort levels for this fishery.

Answer: here

(b) The figure starting this exercise shows that the harvest level that maximizes the profits (rents) from the fishery is greater than the open access harvest level, i.e. $H_{\pi\,max} > H_{OA}$: (i) When this is a case, explain why an aggregate harvest quota $\bar{H} = H_{\pi\,max}$ when individual quotas are non-tradable may not reduce efforts to the profit maximizing level $E_{\pi\,max}$. (ii) Why could tradable quotas still work?

Answer: (i) here

Answer: (ii) here

(c) What are the conditions for this fishery being stable and not threatened by extinction if the net growth function does not decline, for example due to climate change? Explain the reasoning behind your conditions. You may choose to illustrate your solution by a graph.

Answer: here

Question 2 (30 points – 10 points for each sub-question a-c)

The basic standard single rotation timber harvest model for even aged tree stands when replanting occurs at the end of the rotation can be written as: $\pi_T^E = \left(P_T S_T - C_T^E - k_T\right) e^{-Tr}$, where superscript E indicates an even aged tree stand. For a tree stand that reaches its optimal rotation age, T, next year, the discounted profits becomes $\left(P_1 S_1 - C_1^E - k_1\right) e^{-r}$. Similarly, a stand that reaches its optimal rotation age, T, in two years time is then written as: $\left(P_2 S_2 - C_2^{\hat{E}} - k_2\right) e^{-2r}$.

Let there be $T = \tau$ stands where $t = 1, 2, \ldots, \tau$ also indicates age to harvest maturity. The net present value of T equally large stands (for simplicity 1 hectare large) where t is the time before each stand reaches harvest maturity can now be written as:

$$NPV^E = \sum_{t=1}^{\tau} \left(P_t S_t - C_t^E - k_t\right) e^{-tr}$$

- r = the risk-free interest rate,
- P_t = the per volume timber price at the optimal rotation age
- S_t = the timber volume at the optimal rotation age,
- C_t^E = the even aged stand costs of harvesting S_t on a one hectare clear-cut, and
- k_t = the costs of replanting per hectare after the tree harvest.

A forest owner considers select (locked) harvesting, i.e. cutting an equivalent timber volume on a larger area to produce the same volume of timber to avoid for example loss of habitat for certain species from clear-cuts. To simplify matters we assume that the optimal rotation age, $T = \tau$, is the same for select harvesting and clear-cuts. Note that for locked harvests there are no replanting costs, i.e. $k_t = 0$. However, tree harvesting costs are higher for two reasons: First, locked harvests require harvesting over a larger acreage, and second due to damages on remaining trees.

(a) (i) Write down the profit function per harvested tree volume for a randomly chosen time, $1 < t \leq \tau$, for locked harvesting when $C_t^L > C_t^E$. Explain your reasoning for the chosen locked harvest profit function for time t, π_t^L .

(ii) How large are the discounted maximum extra costs to make locked harvesting equally profitable as even stand harvesting for a randomly chosen time , $1 < t \leq \tau$? Show your calculation(s).

Answer (i): here

Answer (ii): here

(b) Suppose net grazing benefits, B_t , for even aged stands lasts for β years after the clear-cut for game species like moose, i.e. grazing benefits occurs early in the rotation. What is the size of these benefits for a randomly chosen plot indexed t. Hint: Hunting benefits could last for the entire duration of a single rotation, i.e. $t + \beta \leq \tau$, or for only parts of the rotation when $t + \beta > \tau$. Note that is the single rotation optimal time for harvesting (clear-cut). Explain your reasoning and show your calculations.

Answer: here

(c) What are the differences in hunting benefits between even aged tree stand management and locked harvest management from (b) under a multiple rotation model? Explain verbally.

Answer: here

Question 3 (40 points – 10 points for each sub-question a-d)

Fossil fuel reserves are likely to last longer than the time it takes under current greenhouse gas (GHG) emissions to reach the accumulated greenhouse gas emission restriction (the climate budget) associated with for example a 2 degrees climate target.

(a) Explain why this allows you to drop the fossil fuel reserve restriction in a model with the objective to maximize welfare for a finite time T years to reach the 2 degrees climate target? Instead, you need to replace the resource constraint by a GHG budget constraint. Why?

Answer: here

(b) Formulate a finite time objective function for a model with both consumer and production externalities. State the appropriate choice variables for the management of greenhouse gas emissions, and explain what these choice variables represent. Also explain any important parameters in this objective function.

Answer: here

(c) (i) Formulate the typical constraints needed for a model with both consumer and producer externalities caused by accumulated GHG emissions. From (a) it follows that it is not necessary with a standard resource constraint for T years. This standard constraint is therefore replaced by an accumulated emission constraint. Explain the terms entering the constraints.

(ii) Express the constrained maximization problem as the current value Hamiltonian specification of the objective function with shadow prices (Lagrangian multipliers) for each of the constraints you have listed. Explain why the shadow price on the GHG budget can be replaced by the price of GHG emissions.

Answer (i): here

Answer (ii): here

(d) Simplify the Hamiltonian you formulated in (c) to only contain the accumulated GHG constraint, i.e. as $H = U(C_t, E_C(A_t)) + P_t(-A_t)$. (i) Explain why this simplification is problematic?

(ii) Suppose that this simplification is unproblematic. Draw a "four corners" graph that captures the effects of this simplified Hamiltonian when a backstop technology arrives rendering GHG emitting production, Z_t , obsolete as the new technology makes net emissions less than zero. Assume that the backstop technology arrives with certainty at time T with a certain price P^B for the substitute of Z_t . Explain your reasoning behind the graph.

Answer (i): here

Answer (ii): here

Jon Olaf Olaussen (external control of questions)

Eirik Romstad (course responsible)