ECN 275/375 – Natural resource and environmental economics
12:15-15:15 April 12, 2023

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 made to reduce the usefulness of ChatGPT. For this test using ChatGPT is not considered a violation of the independent work condition for tests/exams.

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 (Ch. 39, Academic regulations for NMBU).

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

Question 1 (30 points)

Consider the following stock pollution model for accumulated carbon A_t in the atmosphere:

$$\underset{\{C_t,R_t,V_t\}}{MAX} W = \underset{\{C_t,R_t,V_t\}}{MAX} \int_0^{\infty} U(C_t, E(A_t)) e^{-rt} dt$$

s.t.

$\dot{S}_t = -R_t$ (resource stock change)

$\dot{A}_t = M(R_t) - \alpha A_t - F(V_t)$ (climate gas accumulation change)

$\dot{K}_t = Q(K_t, R_t) - C_t - V_t$ (capital change)

where C_t is consumption, R_t is fossil resource use (= extraction), V_t is expenditures used to reduce environmental pressures $E(A_t)$ from accumulated emissions A_t, r is the discount rate, S_t is the stock of the resource, $M(R_t)$ is emissions from resource use, α is the self cleaning factor, $F(V_t)$ are impacts on policy for a given policy expenditure level V_t, $Q(K_t, R_t)$ is production from man-made capital K_t and fossil resource use R_t.

(a) (i) What are the signs of the partial derivatives in all functions in the above setup for the model to capture the tradeoffs between consumption C_t and accumulated emissions A_t. **(5 points)**

(ii) Suppose there is technological progress on policy impacts that grows with a rate γ. Show how this affects the relevant function(s) and alters the model setup (you only need to modify the equation(s) that are affected from this addition. **(5 points)**

Answer: (i) here

(ii) here

(b) (i) How would you modify the model to include a carbon budget for staying below a certain threshold for climate change, for example the 2 degrees' threshold. **(5 points)**

(ii) What implications emerge for the climate gas accumulation change equation in an infinite time horizon model? Explain briefly. **(5 points)**

Answer: (i) here

(ii) here

(c) Draw a four corners graph capturing the situation in (b)(i) when a backstop technology arrives rendering extraction of fossil resources, R_t, obsolete, i.e., the new technology completely replaces fossil resources. Explain your reasoning behind the graph. **(10 points)**

Answer: here

Question 2 (30 points)

Optimal forest rotation lengths are important for the management of even aged forest stands which are conducive for area clear cuts. The basic model is the single rotation model. It provides many insights, but also has its limitations. Multiple rotation models cover a wider array of cases.

(a) This question relates to the single rotation version of this group of models: (i) Show that under *constant net prices*, p_t ,the optimal rotation length, T^A, is given by the formula: $\dot{S}_{T^A}/S_{T^A}=r$. (ii) Explain the intuition behind the formula given in (i). **(10 points)**

Answer:

(i) here

(ii) here

(b) This question also relates to the single rotation version. Suppose there is technological progress in harvesting technologies that are used. (i) Explain how this impacts the formulation of the objective function. (ii) Explain or show how your formulation in (i) changes the optimal solution from (a), and explain the intuition behind your finding. **(10 points)**

Answer: (i) here

(ii) here

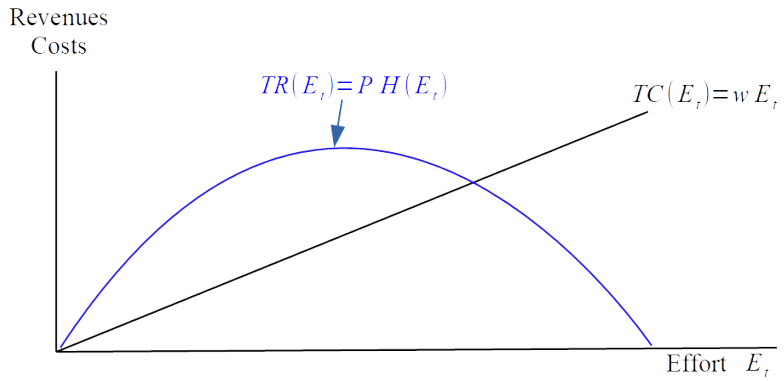
(c) Non-timber benefits. Explain why non-timber benefits occurring early in a single rotation, like hunting, do not affect the rotation age compared to the single-rotation model, but will in the multiple rotation model. **(10 points)**

Answer: here

Question 3 next page

Question 3 (40 points)

The basic open access effort model is often written as $\pi_t(E_t)=P\,H(E_t)-w\,E_t$, where E_t is effort, *P* is the wholesale market price for fish, $H(E_t)$ is harvest as a function of effort, and *w* is the unit costs (wage) of effort. Assume that *P* is one (1). The figure below illustrates the model.



(a) Consider a "virgin" fishery, i.e., fishing occurs on a species that has previously not been fished. Such fisheries have often been unregulated. (i) Explain why the above model is well suited to describe the fishing effort in "virgin" fisheries. (ii) Explain why fisheries managed this way often lead to what is called the "tragedy of the commons". **(10 points)**

Answer: (i) here

(ii) here

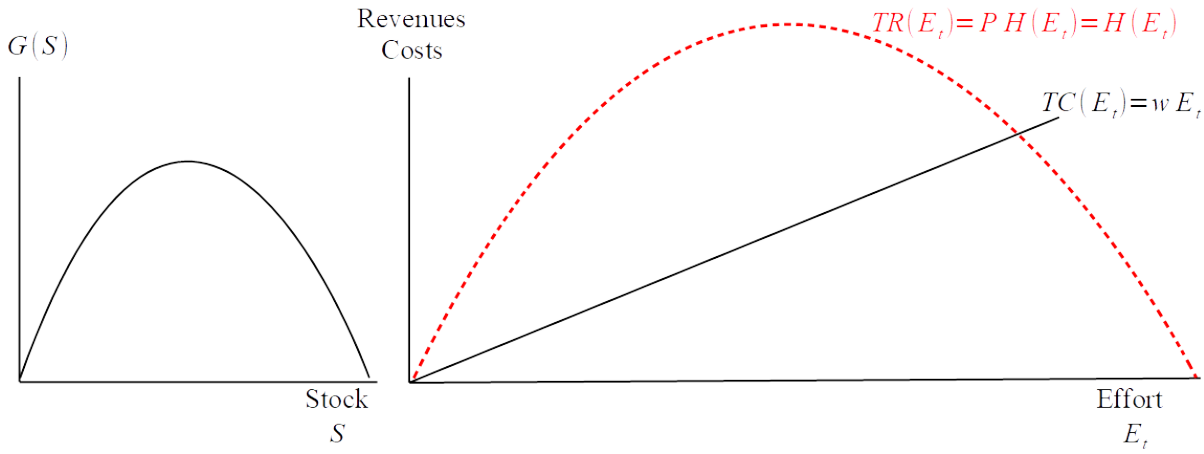
The costs per kilo fished as a function of harvests and stocks can be described by the cost function $C(H_t, S_t)$, which is increasing in harvest, i.e., $C_H(H_t, S_t)>0$, and decreasing in stock size, S_t i.e., $C_S(H_t, S_t)<0$.

(b) (i) Explain how the above information is often consistent with the open access model around the open access equilibrium effort. (ii) What modification(s) of the basic open access model $\pi_t(E_t)=p\,H(E_t)-w\,E_t$ would capture the impact of higher cost from decreased stocks, $C_S(H_t, S_t)<0$ on the fishing effort. **(10 points)**

Answer: (i) here

(ii) here

Information related to parts (c) and (d). The right hand panel in the graph on the next page shows the harvest-effort curve (dashed red line) for a "virgin fishery". The left hand panel of the graph shows the net growth-stock relationship (you will use that in part d). For simplicity let the product price *P* equals one, which gives the total revenue curve $TR(E_t)=H(E_t)$. Assume that the price P=1 remains unchanged over time.



(c) (i) Insert a curve in the graph above to capture the change in the total revenue curve (which with P=1, equals the effort-harvest curve from a "virgin fishery" (red dashed line) to an effort-harvest curve that could lead to a steady). Explain the reasoning behind the curve you added. (ii) Mark the open-access equilibria for the initial situation (dashed red line), and for the effort-harvest curve you added. Given the above graph, explain why the open access effort under the initial situation must lead to declining stocks **(10 points)**

Answer: (i) here

(ii) here

(d) (i) Indicate the profit maximizing effort level. Explain how you found it. (ii) Given the effort-harvest relation you drew, explain why it is sustainable or not. **(10 points)**

Answer: (i) here

(ii) here

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