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Candidate instructions

ECON4910 - Environmental Economics

This is some important information about the written exam in ECON4910. Please read this carefully before you start answering the exam.

Date of exam: Friday, May 31, 2019
Time for exam: 14.30 - 17.30 (3 hours)
The problem set: The problem set consists of 4 questions with several subquestions. They will be given equal weight in the evaluation. Elaborate and explain all your calculated answers. If you believe the text in the problem is imprecise and that you need to make additional assumptions, please state your assumptions clearly as "Assumption 1: .....", etc.

Sketches: You may use sketches on all questions. You are to use the sketching sheets handed to you. You can use more than one sketching sheet per question. See instructions for filling out sketching sheets below. It is very important that you make sure to allocate time to fill in the headings (the code for each problem, candidate number, course code, date etc.) on the sheets that you will use to add to your answer. You will find the code for each problem under the problem text. You will NOT be given extra time to fill out the "general information" on the sketching.

Access: You will not have access to your exam right after submission. The reason is that the sketches with equations and graphs must be scanned in to your exam. You will get access to your exam within 2-3 days.

Resources allowed: No written or printed resources - or calculator - is allowed (except if you have been granted use of a dictionary from the Faculty of Social Sciences).

Grading: The grades given: A-F, with A as the best and E as the weakest passing grade. F is fail.

Grades are given: Wednesday, June 19, 2019

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Question 1. Tradable permits

Suppose there are *n* = 10 identical firms and they emit pollution type A (CO_2) as well as B (SO_2). The aggregate harm for the consumers in the society is $c_A e_A + c_B e_B$, where $c_A = 5, c_B = 10$ and $e_A = \sum_i e_A^i \quad and \quad \sum_i e_B^i$. But it is costly to reduce emission, so each firm benefits from emitting and has the profit function:

$$\pi_i(e_i) = e_A^i(30 - e_A^i) + e_B^i(30 - e_B^i).$$

a. What is the socially optimal level of $CO_2(e_A^i)$?
b. Consider a permit market where a certain number of permits is given to the firms and they can trade them. Suppose furhter that each firm takes as given the prices for buying the right to pollute A, p_A, and B, p_B. Which quantity of e_B^i would firm *i* like to emit, as a function of the two prices?
c. To maximize social welfare, how many total (aggregate for all firms) permits for emitting CO_2 (A) should the industry receive as a whole?
d. If the planner also distribute the optimal number of SO_2 permits (B), what is then the equilibrium market price, p_B?
e. Which allocation(s) of the permits among the firms would you suggest, if you were advising the government? Explain in words and justify your answer.
f. How would your answer in the previous subquestion (e) change if the firms had heterogeneous abatement costs?

Fill in your answer here and/or on sketching paper

c) 25/2, or 12,5 per firm, which is the socially optimal level of CO_2. in total, 10*12,5 = 125 permits.

d) market price PB = 10, when 100 permits are distributed.

e) Since these firms are identical, i would advise the government to give an equal amount to each firm. Then the allocation is already optimal, and transaction costs (if there are any) will not distort the equilibrium.

f) If firms have different (heterogeneous) abatement costs, and there are transaction costs, it would make sense to give more to the firms with high abatement costs, who will not be able to reduce their emissions much, while the firms with high abatement costs can buy as much as they need until their costs of abating equal the cost of buying the permits. The firms with high abatement costs have strong incentives to buy the permits even though there are transaction costs.

Besvart.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

9 9 4 5 4 3 5

Oppgavekode Question code	Dato Date	Emnekode Subject code	Kandidatnummer Candidate number	Oppgavenummer Question number	Sidetall Page number
9945435	31.05	Econ4910	172303	1	1

Tegneområde Drawing area

a)

$C_A = 5$
$C_B = 10$

$U = \Pi - H$

$= \sum \pi_i(e_i) - C_A e_A - C_B e_B$

$= \sum [e_A^i(30 - e_A^i) + e_B^i(30 - e_B^i)] - \sum (C_A e_A^i + C_B e_B^i)$

FOC
e_A^i: $30 - 2e_A^i - 5 = 0$

$25 = 2e_A^i$

$\frac{25}{2} = e_A^i \Rightarrow 125 = e_A$ total CO_2

b) firm now maximizes

$\pi(e_i) = e_A^i(30 - e_A^i) + e_B^i(30 - e_B^i) - P_A e_A^i - P_B e_B^i + P_A \cdot Q_A + P_B \cdot Q_B$

Q_i: quantity of permits given of type i

$\frac{\partial \pi}{\partial e_B^i} = 30 - 2e_B^i - P_B = 0$

$30 - P_B = 2e_B^i$ $\quad e_B^i = 15 - \frac{P_B}{2}$

the firm woul like to emit $15 - \frac{P_B}{2}$ of e_B^i

d) $\frac{\partial U}{\partial e_B^i} = 30 - 2e_B^i - 10 = 0$ $\quad e_B^i = 10$ $\quad$ 10 per firm.
$e_B = 100$

want $e_B^i = 10$ $\quad$ firm sets $e_B = 15 - \frac{P_B}{2}$

$10 = 15 - \frac{P_B}{2}$ $\quad 20 = 30 - P_B$ $\quad P_B = 10$

2 Question 2. Conservation

There are two districts, *A* and *B*, and each $i \in \{A, B\}$ has a stock X_i of forest. If an amount

$x_i \in [0, X_i]$ is illegally extracted, it is supplied to the market and each unit is sold at price *p*:

$$p = P - ax$$

where $x = x_A + x_B$. To discourage illeagal logging on one unit of the forest, the expected penalty when illeagally logging at the unit must be at least as large as the price *p*. The cost of raising the expected penalty at a unit of forest is *c*. The marginal value of conserving the forest $(X_i - x_i)$ is measured by the constant v_i for country *i*.

a. Based on your intuition, what do you think is the effect of a larger *c* on x_A and why?
b. District *A* may take x_B as given when deciding on x_A. Derive a formula showing how x_A depends on *A's* expectation of x_B. Explain the intuition for your formula.
c. Derive a formula showing how the total amount of logging, *x*, depens on *c*. Can you explain the similarity/difference to your answer in the first subquestion, above?
d. Suppose that *B* is goint to decide on x_B at some specific time, *t,* while *A* decide on x_A at a different time, *t'*. How is x_A, x_B and *x* depending on whether $t > t'$, $t < t'$, or $t = t'$?
e. Which of these sequences is preferred by district *A?*
f. Suppose Norway seeks to reduce *x*. How do you suggest that Norway does this, based on your model?

Fill in your answer here and/or on sketching paper

a) If it is more costly to preserve the forest, a district will be able to preserve less, because it costs more than it is worth to them. So, district A will conserve less. District B however, will probably preserve more, because the increased logging in district A, xA will affect market prices negatively. For district B it will thus probably become less expensive to preserve, and thus they will log less.

b) To see how district A will choose their xA i maximize their utility of their forest, which depends on their own value of it, minus the cost of preserving it, which depends on the market price, which also depends on both xA and xB. Thus the utility function looks like the equation on the sheet.
I then maximize it with respect to xA, which is the only variable district A has the opportunity to vary.
The first order condition for xA ends up being equation (1). xA will decrease when the value of the forest increases, and it will increase when total amount of forest in the district increases (there is more to take of, thus more to protect, most likely less will be protected because it its expensive to protect. illegal logging in district A is also decreasing in logging in district B, with the same intuition as in question a. increased logging drives prices down, and therefore cost of protecting, and thus it is optimal to protect more than before xB went up. When A expects a specific xB, A will use their best response xABR(xB), which is given by equation (2). Since the two districts are symmetrical by the model, xB will depend on the same formula as xA, only with the B's and A's exchanged for each other.

c)Since total amount of logging x=xA + xB, x ends up depending on c through equation (4).
If cost of conserving increases, the term -(vA+vB)/3ca becomes smaller (less negative), and thus x increases. This makes sense intuitively too, because when costs of conserving increase for both countries, both will decrease conservation until conservation costs as much as conservation is worth to them again. So, total illegal logging wil increase.

the costs of conservation could easily have been cA and cB by the way, the equation would have been the same except it would have had - vA/3cAa - vB/3cBa instead. I chose to let c be the same for both districts this time.

d) t=t' is the situation we have derived in b, where both follow their own best response to the others choice.
t>t' is a situation where A chooses their x before b, which means that B will have to respond to A's actions, while A gets to choose.

t<t' is the opposite situation from the previous, and the exact opposite will happen. B will choose to conserve less than in the t=t' case, because they know that A will reduce their conservation in response to the higher price of conservation. Thus B is now the winner that gets to conserve more, while A has to pay the price of reducing market prices.

e) District A will want to chose first (t>t'), so that they get to conserve more, while B has to reduce conservation to decrease the market price.

f) If Norway is in a situation where it gets to choose before other logging countries, it would just reduce x and expect the others to compensate for the increased market price.
If it is not in this kind of a situation, Norway's options are to find a way to protect the forests more efficiently, by for example making advances in surveillance technology, to make their costs of protecting go down. If Norway wishes to do this because their v is suddenly higher, then they should just protect more until the cost of protecting more has increased (due to higher market prices) until it equals their value of the forest.

Besvart.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

0 5 8 8 0 8 8

Oppgavekode / Question code	Dato / Date	Emnekode / Subject code	Kandidatnummer / Candidate number	Oppgavenummer / Question number	Sidetall / Page number
0588088	31.05.2019	Econ 4910	172303	2	2

Tegneområde Drawing area

b)

$U(A) = v_A(\bar{X}_A - x_A) - cp(\bar{X}_A - x_A)$

$U(A) = v_A(\bar{X}_A - x_A) - c(P - a(x_A + x_B))(\bar{X}_A - x_A)$

$U(A) = v_A(\bar{X}_A - x_A) - (cP - ca x_A - ca x_B)(\bar{X}_A - x_A)$

$$\frac{\partial U(A)}{\partial x_A} = -v_A + ca\bar{X}_A - 2ca x_A - ca x_B = 0$$

$2ca x_A = ca\bar{X}_A - v_A - ca x_B$

$$x_A = \frac{\bar{X}_A}{2} - \frac{v_A}{2ca} - \frac{x_B}{2} \quad (1)$$

$$x_B = \frac{\bar{X}_B}{2} - \frac{v_B}{2ca} - \frac{x_A}{2} \quad \text{(by symmetry)}$$

$$x_A^{BR}(x_B) = \frac{\bar{X}_A}{2} - \frac{v_A}{2ca} - \frac{1}{2}\left[\frac{\bar{X}_B}{2} - \frac{v_B}{2ca} - \frac{x_A}{2}\right]$$

$$x_A^{BR}(x_B) = \frac{\bar{X}_A}{2} - \frac{v_A}{2ca} - \frac{\bar{X}_B}{4} + \frac{v_B}{4ca} + \frac{x_A}{4}$$

$$x_A\left(1 - \frac{1}{4}\right) = \frac{\bar{X}_A}{2} - \frac{v_A}{2ca} - \frac{\bar{X}_B}{4} + \frac{v_B}{4ca}$$

$$x_A = \frac{4}{3}\left[\frac{\bar{X}_A}{2} - \frac{v_A}{2ca} - \frac{\bar{X}_B}{4} + \frac{v_B}{4ca}\right]$$

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0588088	31.05.	Econ 4910	172303	2	3

Tegneområde Drawing area

$$X_A^{BR}(x_B) = \frac{2}{3}\bar{X}_A - \frac{2}{3}\frac{V_A}{ca} - \frac{\bar{X}_B}{3} + \frac{V_B}{3ca} \quad (2)$$

c) $X = X_A + X_B$

$$X = \frac{2}{3}\bar{X}_A - \frac{2}{3}\frac{V_A}{ca} - \frac{\bar{X}_B}{3} + \frac{V_B}{3ca} + \frac{2}{3}\bar{X}_B - \frac{2}{3}\frac{V_B}{ca} - \frac{\bar{X}_A}{3} + \frac{V_A}{3ca}$$

$$X = \frac{\bar{X}_A + \bar{X}_B}{3} - \frac{(V_A + V_B)}{3ca}$$

Oppgavekode Question code	Dato Date	Emnekode Subject code	Kandidatnummer Candidate number	Oppgavenummer Question number	Sidetall Page number
0588088	31.05	Econ4910	172303	2	4

Tegneområde Drawing area

d)

$$\frac{\partial x_A}{\partial x_B} = -\frac{1}{2} < 0 \qquad \frac{\partial x_B}{\partial x_A} = -\frac{1}{2} < 0$$

(from (1))

$$\Delta x = \Delta x_A + \Delta x_A \cdot \left(-\frac{1}{2}\right)$$

So for Δx_A (which is probably a reduction)

x will be changed by $\left(-\frac{1}{2}\right)\Delta x_A$

if x_A change their x_A by 1 less,

x is reduced by $\frac{1}{2}$.

$$x = (-1) + (-1)\cdot\left(-\frac{1}{2}\right) = -\frac{1}{2}$$

Same if x_B gets to choose first and reduces x_B by 1. X is reduced by half the amount the choosing part reduces by, because the other part has to increase their x by half of it.

3 Question 3. Prices vs. Quantities

a. Weitzman (1974) analyzed the choice between emission taxes and emission quotas when there is uncertainty in the marginal abatement cost. Try to explain the trade-offs involved in words, and the intuition for the optimal instrument choice.

b. Can you illustrate the trade-off (from question a) in (x,y)-diagrams, where you measure the abatement levels at the horizontal axis?

Fill in your answer here and/or on sketching paper

a) and b)

The social planner (or the state if you will) wishes to achieve an optimal level of emissions, such that marginal abatement costs equal the social damage done to society. They have a choice between taxing emissions, or auctioning (or giving out) a certain amount of quotas for emission. In a situation of no uncertainty, there would be no difference between these two choices, and in a situation of uncertainty around damages, there would also not be difference in the choice. Here however there is.

The firm, only cares about their own productivity, and will respond to the price of emitting, and put it against their own marginal abatement cost. If it is more costly to pay the price of emitting, than it is to abate a bit more, they will abate less until the marginal price of abating more is equal to the marginal cost of emitting more.

say marginal abatement costs = c'(E)

firms will set c'(E)=tax (tao) or quota cost (sigma)

Firms will not care about the marginal damages of emitting = D'(E)

So, in a situation of uncertainty about abatement costs, we have an estimated C, in the scantron sheet named C~ (on top of the letter)

So, lets say this estimated C is too low, meaning that real abatement costs are actually higher than what we estimated. See chart 1 in the sheet. E* marks the optimal level of emissions, given by A, and on the y axis we have the prices of the tax or quota. In optimum quota price=sigma* or tax= tao*

However, when we choose the instrument, we only know B, and will set our tax or quota amount assuming this is the optimum.

Here, we will either end up with the estimated emissionlevel of E~, or we will set the tax tao~. they will lead to two completely different realities.

Choosing to allow for E~ emissions, will make the quota price equal sigma~, which is very high, much higher than the optimal price. Too little is being emitted in this scenario, it would have been more efficient to allow producers to emit more. The welfareloss is the triangle between A, B and C.

Choosing a tax rate of tao~ has the opposite effect. The price is way too low, and producers will emit until abatement costs equal the tax, which leads to E(tao~) emissions, which is too much emissions. Again an inefficient solution, where now the deadweight loss is the area between points A, E and D.

Both solutions are inefficient, but in the example chart it is hard to say which deadweight loss is smaller, and therefore which instrument is better.

We get the same results in the case where abatement costs end up being lower than anticipated, but with opposite results(tax will lead to too little emission, and quotas will lead to too much).

If we know something about the steepness of the damage curve, we can say something about which instrument will most likely lead to the smallest deadweight loss (we can probably not avoid a deadweight loss in uncertainty).

i will provide two different charts with examples of scenarios where either of the instruments is better. lets say the problem is the same as in chart 1. Abatement costs end up being higher than estimated.

In chart 2 the marginal damage curve is relatively flat, and this has an effect on the estimated solutions. We can see that the deadweight loss of the quotas (triangle between A,B and C) is larger than for the tax (triangle between A, D and E). So, the tax is the way to go in this economy. This is because having more emissions than optimal is not as damaging as having too little production. We will set a tax on emission.

In chart 3 the damage curve is steep, which means that damage is much more costly on the margin, as emissions get higher.

Now it is pretty clear that the deadweight loss of the tax is much bigger than the deadweight loss of quotas. This is because having too much emission is much more costly than having too little. We will make E~ quotas.

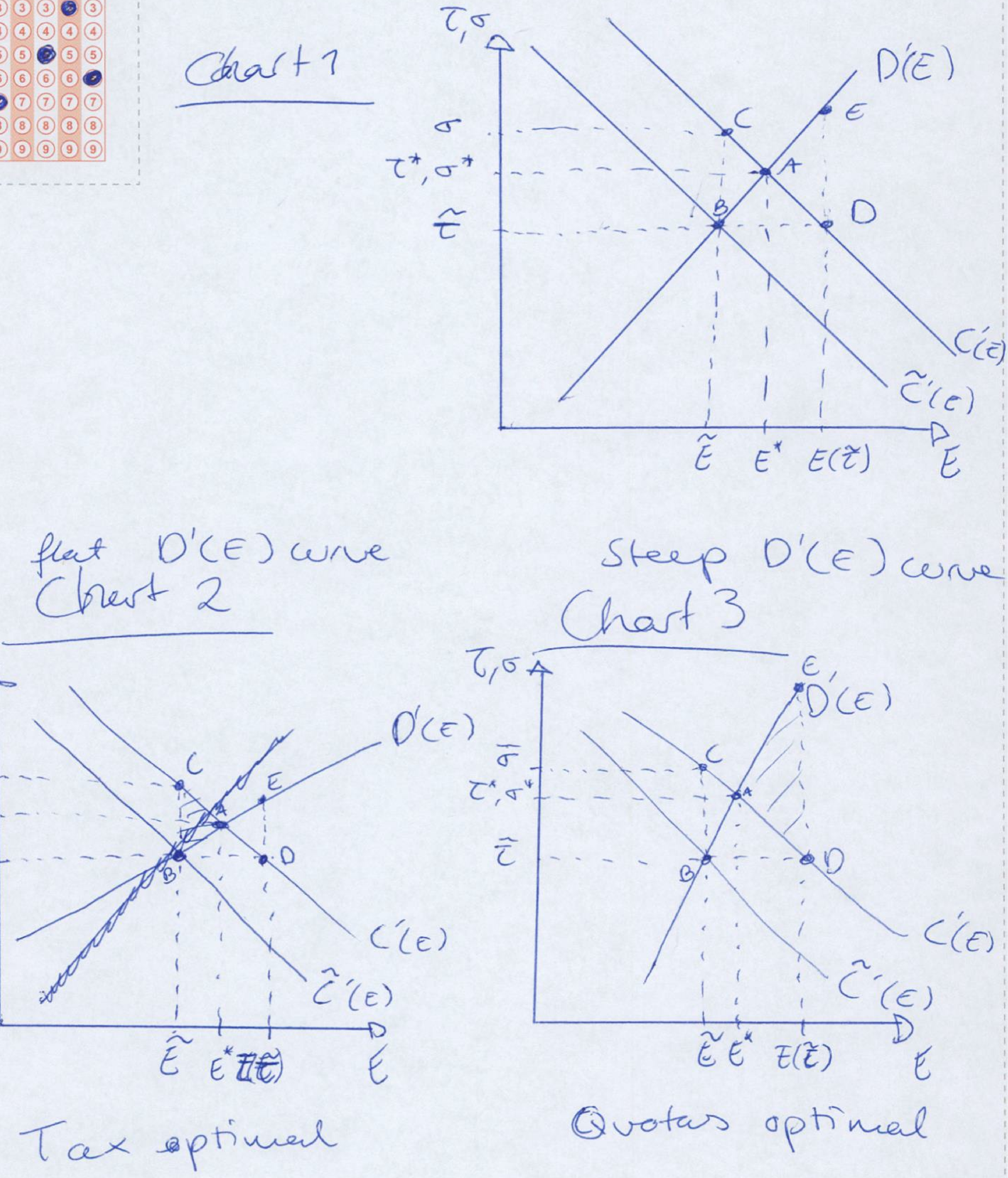
Besvart.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

5 8 7 2 5 3 6

Oppgavekode / Question code	Dato / Date	Emnekode / Subject code	Kandidatnummer / Candidate number	Oppgavenummer / Question number	Sidetall / Page number
5872536	31.05.2019	Econ 4910	172303	3	5

Tegneområde Drawing area



4 Question 4

i. Explain how emissions affect welfare and how this relation will be depicted in a typical integrated assessment model of climate change. You can, but you do not have to, use formulas, but make sure to explain all steps.

Fill in your answer here and/or on sketching paper

IAMs usually have equations to show the objective function (welfare maximization), the production function, and some to show the climate, through equations for the temperature and carbon stocks, and for the interface between the economy and the climate, through a damage function and abatement costs.

In a typical IAM, using these equations, emissions affect welfare directly in two ways. Through the productivity of emissions in production, and through the damage made by the emissions. Example equations are provided in the sheet. The rest of the potential welfare funcion is not provided.
The damage on u comes from that people have a disutility of damage to the environment. This damage can be many things, for example that changes in temperature leads to more extreme weather, floods, droughts, disease, etc. Mt is the carbon stock, which affects temperature, which in turn damages the environment. The parameter Xi is a measure of how destructive greenhouse gasses are. It is usually convex in emissions, which means marginal damage is increasing.
The productivity term shows us that emitting helps us produce, and people utility of consumption. Emitting more allows us to consume more. w is a term for the productivity of emissions. w is usually below 1, which means that there are decreasing returns to scale from emitting. The marginal productivity in emissions is concave.
Choosing how much to emit is a payoff between the damages of emissions and the utility of consumption.

ii. Explain the difference between the "optimal" scenario in the DICE integrated asessment model and the "Stern" scenario. In what assumptions do they differ? Why? Which is "optimal"? How do they differ (or coincide) in their policy recommentdations?

Fill in your answer here and/or on sketching paper

The main difference in these two models is the choice in the discount rate. The DICE model by Nordhaus uses a discount rate based on the market discount rates because he believed this reflected the valuation people put on the future. The stern scenario however uses a discount rate of 0,01, which is much much lower than Nordhaus used, and much lower than anyone else had used before. This is because he believed this was a moral question, and that the value of future generations having a future and a world in which to live, could not be priced by the normal discount rate.
The assumption about the social rate of time preference is the main reason why the two discount rates differ.

So, the stern scenario puts a much higher value on the future than the DICE model. This results in a bigger reaction in regards to carbon pricing, taking control over emissions, which results in a temperature change that is smaller than in the DICE.
Both scenarios are optimal, given their own assumptions. One would never solve a model without finding the optimal given the assumptions taken. The discussion is rather on whether the assumptions taken are correct, and which are better.

It can be argued that both is better than the other, it only depends on the rationale applied.

Besvart.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

7 3 3 6 5 7 4

Oppgavekode Question code	Dato Date	Emnekode Subject code	Kandidatnummer Candidate number	Oppgavenummer Question number	Sidetall Page number
7336574	31.05.24	Econ4910	172303	4	6

Tegneområde Drawing area

damage $e^{-\xi M_t}$

productivity E_t^{ω} E : emissions

$U=$ some term $\cdot\ e^{-\xi M_t} E_t^{\omega}$