Written Exam at the Department of Economics summer 2020

Economics of the Environment and Climate Change

Final Exam

June 4, 2020

(3-hour open book exam)

Answers only in English.

This exam question consists of 4 pages in total, including this front page.

The paper must be uploaded as <u>one PDF document</u>. The PDF document must be named with exam number only (e.g. '127.pdf') and uploaded to Digital Exam.

This exam has been changed from a written Peter Bangsvej exam to a take-home exam with helping aids. Please read the following text carefully in order to avoid exam cheating.

Be careful not to cheat at exams!
You cheat at an exam, if you during the exam:

- Copy other people's texts without making use of quotation marks and source referencing, so that it may appear to be your own text. This also applies to text from old grading instructions.
- Make your exam answers available for other students to use during the exam
- Communicate with or otherwise receive help from other people
- Use the ideas or thoughts of others without making use of source referencing, so it may appear to be your own idea or your thoughts
- Use parts of a paper/exam answer that you have submitted before and received a passed grade for without making use of source referencing (self plagiarism)

You can read more about the rules on exam cheating on the study information pages in KUnet and in the common part of the curriculum section 4.12.

Exam cheating is always sanctioned with a warning and dispelling from the exam. In most cases, the student is also expelled from the university for one semester.

Written exam in the Economics of the Environment and Climate Change, Spring 2020

OPTIMAL CLIMATE POLICY

In the following you will be asked to analyse the optimal climate policy using a highly simplified model of the interaction between the economy and the climate system. When you have carried out the formal analysis, you are invited to discuss the limitations of the model.

The timeline in the model is divided into two periods which can be thought of the as "the present" and "the future". We will use the following notation:

C_i = consumption in period i, i = 1,2
K = investment in period 1 = capital stock in period 2
E = emission of CO_2 in period 1
A = investment in abatement of CO_2 emissions in period 1
D = damage cost of climate change in period 2
$u(C_i)$ = utility from consumption in period i, i = 1,2
U = lifetime utility of the representative consumer
Y = output in period 1 (exogenous)
r = real rate of return on capital (exogenous)
ρ = utility discount rate (exogenous)

The lifetime utility of the representative consumer is

$$U = u(C_1) + \frac{u(C_2)}{1+\rho}, \qquad u'(C_i) > 0, \qquad u''(C_i) < 0, \qquad i = 1,2. \tag{1}$$

At the beginning of period 1, the economy is endowed with a predetermined capital stock, which generates an amount of output Y in period 1. During period 1, the existing capital stock is fully worn out, but a part of period 1 output can be accumulated as a new capital stock for use in period 2. Another part of period 1 output can be invested in abatement equipment A which can be used to reduce CO_2 emissions in period 1. Hence the amount of output left over for consumption in period 1 is

$$C_1 = Y - K - A. \tag{2}$$

In period 2, the capital accumulated during period 1 generates an amount of output $(1+r)K$, but the CO_2 accumulated in the atmosphere during period 1 leads to climate change which causes an output loss D in period 2, so consumption in that period is

$$C_2 = (1+r)K - D. \tag{3}$$

The damage cost in period 2 due to emissions in period 1 is

$$D = \beta E, \qquad \beta > 0, \tag{4}$$

where β is a constant. Emissions in period 1 vary positively with output but can be mitigated through abatement effort. Hence emissions are given by the following function where *a*, *b*, and θ are constant parameters:

$$E = aY - \frac{b}{\theta}A^{\theta}, \qquad a > 0, \quad b > 0, \quad 0 < \theta < 1. \tag{5}$$

The society considered can increase future consumption and welfare in two ways: it can invest in man-made capital, *K*, or it can invest in "natural capital" by undertaking abatement, *A*, which reduces the future damage cost of climate change. Both forms of investment involve some sacrifice of current consumption, as indicated by (2). The socially optimal investment policy is the combination of *K* and *A* that maximizes the lifetime utility (1) of the representative consumer.

Question 1. Use equations (2) through (5) to write the lifetime utility function (1) in terms of *K* and *A*.

Question 2. Use your result in Question 1 to show that society's optimal investment policy implies that

$$\beta b A^{\theta-1} = 1 + r. \tag{6}$$

Give an economic interpretation of this result and explain the intuition behind it.

Question 3. Solve equation (6) for the optimal abatement effort *A* and explain intuitively how the various parameters/exogenous variables in (6) affect the optimal abatement effort.

Question 4. Use (5) to derive the marginal abatement cost *MAC*, i.e., the cost of reducing emissions by an extra unit. Is the *MAC* constant, increasing or decreasing? Briefly explain the intuition.

Question 5. Derive an expression for the Social Cost of Carbon (*SCC*), defined as the welfare cost of emitting an extra unit of CO_2. (Hint: Derive the effect on lifetime utility of emitting an extra unit of CO_2 in period 1. Then divide by the marginal utility of consumption in period 1 to obtain a welfare measure expressed in units of current consumption and use the first-order condition for the optimal choice of *K*). Give a brief, intuitive explanation for your result.

Question 6. Show that the result in *Question 2* can be restated in terms of *MAC* and *SCC* and explain the intuition behind it.

Question 7. Now suppose that the economy considered is organized as a market economy where the representative firm's total pollution-related costs in period 1 are

$$TC = A + \tau E, \tag{7}$$

where τ is a carbon tax levied by the government. As part of its maximization of profits, the firm chooses the abatement effort that minimizes its total pollution-related costs *TC*, given that emissions are determined by (5). Derive an expression for the value of τ that will implement the socially optimal abatement effort. Explain the intuition for your result.

Question 8. Apart from dividing time into only two periods, the model above is of course highly simplified in many ways. Discuss some of the complications that are left out from the model but which real-world policy makers have to face when designing a rational climate policy.