Written Re-exam at the Department of Economics winter 2019-20

Economics of the Environment, Natural Resources and Climate Change

Final re-exam

11 February 2020

(3-hour closed book exam)

Answers only in English.

This exam question consists of 4 pages in total

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- leave the examination.
- contact your GP and submit a medical report to the Faculty of Social Sciences no later than five (5) days from the date of the exam.

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You cheat at an exam, if during the exam, you:

- Make use of exam aids that are not allowed
- Communicate with or otherwise receive help from other people
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- Or if you otherwise violate the rules that apply to the exam

Exercise 1. Prices vs. quantities with correlated shocks (indicative weight: 3/4)

Consider an economy where economic activities cause pollution emission. Denote the quantity of pollution emission Q. Without regulation, the economy emits $Q_0 > 0$ units of pollution emission.

Pollution emission reduces economic welfare. The marginal social cost or the marginal damage cost (MDC) of pollution emission is given by:

$$MDC(Q) = bQ + \eta, \quad b > 0,$$

where η is a stochastic shock variable.

Firms in the economy can reduce pollution emission through costly pollution abatement activities. On an aggregate level, the marginal abatement costs are given by:

$$MAC(Q) = c(Q_0 - Q) + \theta, \quad c > 0,$$

where θ is a stochastic shock variable.

The two stochastic variables have zero means and constant variances:

$$\mathrm{E}[\theta] = \mathrm{E}[\eta] = 0, \quad E[\theta^2] = \sigma_\theta^2 > 0, \quad \text{and} \quad E[\eta^2] = \sigma_\eta^2 > 0.$$

However, the covariance between θ and η is assumed constant but not necessarily equal to zero. Specifically, the covariance is given by:

$$\mathrm{cov}(\theta, \eta) = \mathrm{E}\left[(\theta - \mathrm{E}[\theta])(\eta - \mathrm{E}[\eta])\right] = \mathrm{E}[\theta\eta] = \gamma.$$

If γ is positive, the two stochastic variables are likely to move in the same direction. Hence if θ is positive, it is likely that η is positive as well and vice versa.

If γ is negative, the two stochastic variables are likely to move in the opposite direction. That is, if θ is positive, it is likely that η will be negative and vice versa.

Finally, if γ equals zero, the realizations of the two stochastic variables are completely independent.

This exercise will examine under which conditions it is preferable to regulate the economy using a pollution tax or a cap-and-trade system. Importantly, the realisations of the stochastic variables are unknown when deciding on the regulation scheme.

Question 1.1

Explain why a pollution tax and a cap-and-trade system result in the same allocation if there is only uncertainty about marginal damage costs.
[Hint: it may be useful to draw a diagram.]

Question 1.2

Derive the emission level, $\tilde{Q}$, that minimizes the expected net social cost from pollution emission as well as the associated pollution price, $\tilde{t}$.

Question 1.3

A regulator minimizes the expected net social cost of pollution emission using either a pollution tax or a cap-and-trade system. For the cap-and-trade system this is done by setting the emission cap, Q_{permit}, equal to $\tilde{Q}$. Accordingly, the actual emission level (the emission level after shocks have been realized) under a cap-and-trade system equals $\tilde{Q}$.

Show that if the regulator uses a pollution tax, the actual emission level, denoted Q_{tax}, is:

$$Q_{\text{tax}} = \tilde{Q} + \frac{\theta}{c}.$$

Briefly explain this result.

Question 1.4

The optimal emission level, Q^*, is the optimal level of pollution emission given the two stochastic shocks. The regulator cannot implement this emission level, as the shocks are realized after he/she determines the policy, but it is a useful benchmark that we will use later in this exercise.

Derive the optimal emission level. Comment briefly on the difference between $\tilde{Q}$ and Q^*.

Question 1.5

Define the social loss function:

$$SL = \int_{Q^*}^{Q} [MDC(q) - MAC(q)]\, \mathrm{d}q.$$

Explain this function. Specifically, why does this function capture the social loss from an emission level Q different from the optimal emission level Q^*? You may limit your answer to the case $Q > Q^*$.

Question 1.6

The social loss function can be rewritten as:

$$SL = \frac{1}{2}(b+c)\left(Q^2 - Q^{*2}\right) + (\eta - cQ_0 - \theta)\left(Q - Q^*\right).$$

The social loss of the pollution tax, SL_{tax}, and the cap-and-trade-system, SL_{permit}, are given by:

$$\begin{aligned} SL_{\text{tax}} &= \frac{1}{2}(b+c)\left(\left(\tilde{Q} + \frac{\theta}{c}\right)^2 - Q^{*2}\right) + (\eta - cQ_0 - \theta)\left(\tilde{Q} + \frac{\theta}{c} - Q^*\right) \\ SL_{\text{permit}} &= \frac{1}{2}(b+c)\left(\tilde{Q}^2 - Q^{*2}\right) + (\eta - cQ_0 - \theta)\left(\tilde{Q} - Q^*\right). \end{aligned}$$

The function Δ is defined as:

$$\Delta \equiv SL_{\text{tax}} - SL_{\text{permit}}.$$

It can be shown that Δ is given by:

$$\Delta = \left(\frac{b-c}{2}\right)\left(\frac{\theta}{c}\right)^2 + \left((b+c)\,\tilde{Q} + \eta - cQ_0\right)\left(\frac{\theta}{c}\right).$$

Find the expected value of Δ. Explain why the expected value of Δ is a useful metric when deciding between a pollution tax and a cap-and-trade system.

Question 1.7

Consider the special case $\gamma = 0$. Under what conditions will the regulator prefer the pollution tax and the cap-and-trade system, respectively? Carefully explain the intuition behind your results.

Question 1.8

Consider the two cases $\gamma > 0$ and $\gamma < 0$. Explain for both cases which instrument (pollution tax or cap-and-trade system) that is favoured by a non-zero covariance between η and θ compared to a situation where γ equals zero. Explain your result intuitively for the case $\gamma > 0$.

[Hint: to explain the intuition for $\gamma > 0$ it may be useful to draw a situation where both shocks have positive realizations.]

Exercise 2: The Environmental Kuznets Curve (indicative weight: 1/4)

(Hint: You may provide purely verbal answers to the questions in this exercise, but you are also welcome to include equations if you find it useful)

Question 2.1

Briefly explain what an Environmental Kuznets Curve is.

Question 2.2

Explain the mechanism generating an Environmental Kuznets Curve in the Green Solow model.

Question 2.3

Discuss one other economic mechanism that may generate an Environmental Kuznets Curve.