Written Exam at the Department of Economics winter 2020-21 R

Advanced Economics of the Environment and Climate Change

18 February 2021

(3½ hour open book exam)

Answers only in English.

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 question consists of 5 pages in total

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.

Optimal unilateral climate policy and border carbon adjustments

(indicative weight: 3/4)

Consider a small open economy with two production sectors: light, l, and heavy, h, manufacturing. There are two types of consumption goods: one produced by each sector. Consumers derive utility from the consumption of these two consumption goods.

In the following description of the economy, units are chosen such that one unit of fossil fuel consumption leads to one unit of (carbon) emissions.

The utility level of the representative consumer is given by: $u(c_l, c_h)$, where c_l and c_h measure consumption of good l and h, respectively. The utility function is strictly increasing and concave in both arguments.

The representative consumer maximizes utility given its budget constraint and taking prices, aggregate variables, and policies as given. The budget constraint is given by:

$$I = c_l(p_l + t_l) + c_h(p_h + t_h),$$

where I is income, p_l and p_h are the international exogenous prices of consumption good l and h, and the domestic prices of good l and h are $(p_l + t_l)$ and $(p_h + t_h)$. The domestic price of good l (h) equals the international price of good l (h) plus the tariff on good l (h). This tariff is denoted t_l (t_h).

Production in both sectors requires a fossil fuel input. Each sector is represented by a single firm that maximizes profits taking prices, aggregate variables, and policies as given. Profits in the two sectors, π_l and π_h, are given by:

$$\pi_l = f_l(e_l)(p_l + t_l) - e_l(p_e + \tau_l), \quad f_l'(e_l) > 0, \quad f_l''(e_l) < 0,$$
$$\pi_h = f_h(e_h)(p_h + t_h) - e_h(p_e + \tau_h), \quad f_h'(e_h) > 0, \quad f_h''(e_h) < 0,$$

where $f_l(e_l)$ and $f_h(e_h)$ are the production of consumption good l and h, e_l and e_h measure the input of fossil fuels in sector l and h, and τ_l and τ_h are sector specific carbon taxes.

Note that t_l (t_h) is an export subsidy if the economy is a net exporter of good l (h). Meanwhile, it is a tariff on imports if the economy is a net importer of good l (h).

There is no domestic production of fossil fuels, and thus, all fossil fuels are imported.

Trade must balance, implying that the value of net imports equals zero:

$$p_l m_l + p_h m_h + p_e \left(e_l + e_h\right) = 0, \quad m_l = c_l - f_l(e_l), \quad m_h = c_h - f_h(e_h),$$

where m_l and m_h are net imports of good l and h.

The government keeps a balanced budget. The entire tax revenue is transferred to the representative consumer through a lump-sum transfer, T:

$$T = \tau_l e_l + \tau_h e_h + t_l m_l + t_h m_h.$$

The representative consumer has two sources of income: (1) profits from the domestic firms, and (2) the lump-sum transfer from the government. Thus, the representative consumer's income is given by:

$$I = T + \pi_l + \pi_h.$$

Carbon leakage occurs through changes in trade patterns. The amount of carbon leaking to the foreign economy when the value of net imports increases is given by:

$$\begin{aligned}
&\mathscr{L}_l = \left(m_l - m_{0,l}\right) L_l, \quad L_l > 0, \\
&\mathscr{L}_h = \left(m_h - m_{0,h}\right) L_h, \quad L_h > 0,
\end{aligned}$$

where $m_{0,l}$ and $m_{0,h}$ are the net imports of good l and h without regulation, and L_l and L_h are constant leakage rates associated with imports. Specifically, L_l and L_h measure the increase in foreign emissions caused by a unit increase in net imports of good l and h.

Finally, to avoid corner solutions, it is assumed that:

$$\begin{aligned}
&\lim_{c_l \to 0} u_l'(c_l, c_h) = \infty, \quad \lim_{c_h \to 0} u_h'(c_l, c_h) = \infty, \\
&\lim_{e_l \to 0} f_l'(e_l) = \infty, \quad \lim_{e_h \to 0} f_h'(e_h) = \infty,
\end{aligned}$$

where $u_l'(c_l, c_h)$ and $u_h'(c_l, c_h)$ denote the partial derivative of $u(c_l, c_h)$ with respect to c_l and c_h, respectively. These technical assumptions ensure that the representative consumer always demands both types of goods, and there will be domestic production of both goods in a market equilibrium.

Question 1.1

What carbon leakage channels are not present in the model? Your answer should give a short description of each of these channels.

Question 1.2

Characterize the optimal behavior of consumers and firms in the market equilibrium of this economy given some policy (that is some values of τ_l, τ_h, t_l, and t_h).

The government wants to maximize the representative consumer's utility, but it also wants to reduce global emissions. Specifically, the government has the emission target, $\bar{E}$, which consists of domestic emissions and carbon leakage:

$$\bar{E} = e_l + e_h + \mathscr{L}_l + \mathscr{L}_h. \tag{1}$$

Question 1.3

Show that the optimal allocation given the government's emission target, (1), implies that:

$$u_l'(\cdot) = \lambda p_l + \eta L_l, \quad u_h'(\cdot) = \lambda p_h + \eta L_h,$$
$$\lambda f_l'(e_l) p_l + \eta f_l'(e_l) L_l = p_e \lambda + \eta, \quad \text{and} \quad \lambda f_h'(e_h) p_h + \eta f_h'(e_h) L_h = p_e \lambda + \eta,$$

where λ is the shadow cost (negative shadow price) of imports, and η is the shadow price of emissions. Explain these equations intuitively. *Hint: the government wants to maximize the representative consumer's welfare under the emission constraint and the terms-of-trade constraint.*

Question 1.4

Characterize the optimal climate policy (the optimal choice of t_l, t_h, τ_l, and τ_h) given the emission target (1). Briefly explain the regulation in words.

Question 1.5

The government now moves to a purely domestic emission target. Specifically, the government wants to ensure that:

$$\tilde{E} = e_l + e_h. \tag{2}$$

Characterize the optimal climate policy, when the emission constraint is given by (2). Comment on your findings.

Consider the situation from before, where the government's emission target is given by (1). Now assume that the government cannot implement the border carbon adjustment mechanism without facing a costly trade war.

Question 1.6

Show that - in this particular setting - the government can implement the optimal allocation under emission constraint (1) using sector-specific carbon taxes and good-specific consumption taxes. Explain the intuition. Please denote the consumption taxes by $\tilde{t}_l$ and $\tilde{t}_h$. *Hint: you need to remove the border carbon adjustments from the model and implement the consumption taxes appropriately.*

Exercise 2: Environmental regulation under uncertainty (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)

Economists typically argue that a tax on pollution emission and a cap-and-trade system can implement the optimal emission level if there is no uncertainty about pollution abatement costs and pollution damages.

Assume that pollution abatement costs and pollution damage costs are convex. This implies that the marginal abatement cost is increasing in the emission reduction, and that marginal damages are increasing in the emission level.

Question 2.1

Explain how the convexity of the cost functions are connected to the trade-off between a tax and a cap-and-trade system when there is uncertainty about pollution abatement costs.

Question 2.2

Assume that all countries in the world decide to price CO_2e emissions to mitigate climate change. Discuss whether they should implement a tax or a cap-and-trade system.