Exam - environmental economics, Spring 2020

Each subquestion can give at most 5 points.

If you believe the text is imprecise and that you need to make additional assumptions, please state your assumptions clearly as "Assumption 1:...", etc.

Write and draw clearly.

1. Prices vs Quantities

Consider a country with consumers that suffers $C(g)$ from the pollution g, and a large number of identical firms. The benefit for the firms is given by $B(g) \equiv \pi(g) - \pi(0)$, defined as the difference in aggregate profit if the firms can pollute g rather than nothing.

a. Illustrate the market equililbrium for g if there is no regulation, both graphically and mathematically, and compare it to what you consider to be "first best".

Key: Formally: $B'(g) = 0$. Graphically: When the downward-sloping curve $B'(g)$ crosses the horizontal axis. The first best is when the curves cross: FOC $C'(g) = B'(g)$.

b. Discuss: (i) Is the problem incorrect prices — and if so, why (explain)? (ii) Is the problem that there is a missing market – and if so, why (explain)? (iii) Is the problem that there is an externality – and if so, why (explain)? (iv) Is the problem that there is a public good – and if so, why (explain)? (v) Is the problem that there are imperfectly defined property rights – and if so, why (explain)?

Key: All of (i)-(v) are correct, since the problem can be interpreted in several ways.

c. Which of (i)-(v) fits best for climate change? Explain.

Key: Given the international problem, externalities (iii) is natural. Given the symmetry of the impacts, public goods (iv) is also natural. It is most important that the student reasons well.

d. What policies – prices or quotas – do you suggest to implement g if there are uncertainties in the C function only? And what if there are uncertainties only in the B function? Please use a figure to explain.

Key: Optimal: If there are uncertainties in the C' function only, and not in the B' function, then p and q gives the same inefficiency loss (and the same g), but with uncertainties in the B' function, then the efficiency loss is smaller with a tax than a quota iff $C' < -B'$. This is easy to illustrate in a figure.

e. Both prices and quotas lead to inefficiency losses when there are uncertainties in the B' functions only. In particular, suppose $B(g) = g - (g+\theta)^2/2$, where $\theta \in \{0,1\}$. Can you design a better policy than the prices and the quotas, discussed in question d?

Key: Yes, the first best can easily be implemented.
F.ex: a quota combined with a ceiling or a floor for the price (triggering larger/smaller quotas).

2. Repeated games.
Suppose $B(g_i + R_i)$ is every country's i's benefit of emtting $g_i \in \{\underline{g}, \overline{g}\}$, where R_i is the energy produced from the renewables. The environmental cost is $C\left(\sum_j g_j\right) = \sum_j g_j$. Let there be n countries.
a. Under which conditions is the set of emission-decisions similar to a prisonner dilemma game? Do you think these conditions hold in reality?

Key: PD game iff Nash equilibrium is $\overline{g}$ even though moving to $\underline{g}$ is a Pareto improvement, i.e.:

$$\begin{aligned} B(\overline{g} + R_i) - \overline{g} &> B(\underline{g} + R_i) - \underline{g}, \forall i, \text{ and} \\ B(\overline{g} + R_i) - n\overline{g} &< B(\underline{g} + R_i) - n\underline{g}. \end{aligned}$$

b. Suppose the common discount factor is δ. Let $R_i = R$ be fixed. Under which condition is there an equilibrium where everyone emits little? What strategies support this equilibrim? Do you find them to be realistic?

Key: Condition:

$$\begin{aligned} \frac{B(\underline{g} + R) - n\underline{g}}{1-\delta} &\geq B(\overline{g} + R) - \overline{g} - (n-1)\underline{g} + \delta \frac{B(\overline{g} + R) - n\overline{g}}{1-\delta} \Leftrightarrow \\ \delta &\geq \frac{[B(\overline{g} + R) - \overline{g}] - [B(\underline{g} + R) - \underline{g}]}{(n-1)(\overline{g} - \underline{g})}. \end{aligned}$$

Strategies: Trigger (BAU as soon as some $\overline{g}$).

Realistic: Well, on the one hand it is reasonable that if someone stops cooperating then this can threaten cooperation by others in the future. On the other hand, the punishment may be less than that above because countries have incentives to renegotiate and start again, or because of imperfect information or cooperation among the remaining countries. Thus, the condition above is under a penalty that may be stronger than in reality, implying that it is necessary but insufficient that the inequality above holds.

c. How does the answer in b change if R increases?

Key: The RHS of the above inequality decreases in R iff

$$B'(\overline{g}+R) < B'\left(\underline{g}+R\right),$$

which holds if B' is decreasing, i.e., if B is concave. In this case, a larger R makes cooperation an equilibrium for a larger set of δ's, under similar strategies, and the larger scope for cooperation can also make these types of strategies more likely to be reasonable. (Reason: They are less likely to lead to punishments if countries are willing to cooperate instead of defecting.)

d. The Paris Agreement emphasizes transparency, so that it is easier to observe countries' compliance to their promised emission cuts. What is the benefit or effect of that, in the model here? What are the consequences for the necessary level of R?

Key: One interpretation is that the countries can observe each others' emission level more frequently. This means that δ increases, so that the inequality above is more likely to hold. (One free-riders for a shorter time before one is detected.) That is, the compliance constraint holds for a larger set of R's and the lowest R permitting the compliance constraint to hold is reduced. (I.e., countries can reduce the over-investment in renewables.)

Solution sketch for Exam Question Environment Spring 2020:

i) See lecture slides.
Summary: Rate of pure time preference + growth discounting term, which is composed of consumption elasticity of marginal utility and growth rate. I expect an interpretation of these terms, e.g., the pure rate of time preference discounts future utility, intrinsically devaluing the future. The growth discounting terms represents how much the marginal utility for future consumption falls relative to present consumption because of economic growth.

ii) The environmental and the produced goods are, generally, of limited substitutability. Because produced consumption grows faster than environmental goods (Note: that is to be inferred from a discussion we had in a couple of closely related discussions in the lecture or from the graph), the marginal value of the scarcer environmental good grows relative to that of produced consumption.
In the case where theta=1 both goods are fully substitutable and this relative price effect is zero. The lower is theta, the less substitutable the two goods, and the larger the relative price effect.

iii) Translated into the discount rate, the relative price effect will reduce the environmental discount rate. We will give relatively more weight to the environmental amenities in the future because they are growing relatively more scarce in the future.

iv) The Social Cost of Carbon (SCC) is the discounted sum of future marginal damages from an additional unit of emissions today (or in some period t). Given that climate change affects ecosystems and environmental services particularly strongly we conjecture that placing relatively more weight on environmental goods in the future (as/if deduced in iii) increases the SCC. We are looking for a reasonable discussion how SCC is affected. In principle, effect could actually also go the other direction, what we want to see is some conjecture and a reasonable economic argument for it.
(Note: I have shown a slide from the Sterner & Person paper showing how emissions drop faster und limited substitutability. Present graphs and RPE analysis stem from a recent JEEM by Drupp & Haensel.)

v) Equations that change:
   a. Utility function as already specified in the question.
   b. At the very least one additional equation is needed to specify environmental goods and how they are affected by climate change and evolve (or not evolve) over time. This equation can take many forms but importantly must contain some form of baseline evolution of the environmental good and a damage term that reduces the availability of the environmental good as temperature (of CO2) increase.