Economics 134 Fall 2023 Midterm 2

November 15, 2023

Write your name and UID in the upper right corner of each page.

You have 75 minutes to complete this exam. Show your work.

QUESTION 1 (18 points).

True or false.

(a) Uncertainty about climate physics, as well as disagreement about how to value future generations' consumption, will lead to a wide range of possible social costs of carbon.

Solution: True.

(b) On average, poorer, colder countries are more vulnerable to the excess mortality impacts of climate change than richer, hotter countries.

Solution: False. Colder countries appear less vulnerable to the excess mortality impacts than hotter countries.

(c) Ideas are a public good.

Solution: True.

(d) In the free market outcome of a common-pool resource problem, each firm will extract less than if there were no common-pool externality, but more than the first-best.

Solution: True.

(e) Individuals may have incentives to misreport their value of a public good to the government.

Solution: True.

(f) If environmental damages depend on the total pollution across many firms, as well as each firm's pollution, a "command-and-control" policy may lead to greater welfare than a "cap-and-trade" that limits the total quantity of pollution and allows firms to trade credits to pollute.

Solution: True. (For environmental markets to (always) strictly improve on command-and-control, we need environmental damages to depend (only) on the aggregate quantity of pollution; damages can't also depend on each firm's pollution.)

QUESTION 2 (60 points). Global climate change.

There are N countries. Each country i obtains payoffs of

$$2k_i - \frac{1}{3}k_i^2 - D_i(K)$$

from emitting k_i tons of carbon, where $K = \sum_{i=1}^{N} k_i$ denotes total carbon emissions across all countries and $D_i(K) = \theta_i K$ denotes climate damages.

Suppose $N = 10$ and $\theta_i = \frac{1}{10}$ for all i.

(a) If country i maximizes its payoffs, what level of carbon emissions will it choose? What are total emissions if each country maximizes its own payoffs?

Solution: The FOC is $2 - \frac{2}{3}k_i^* - \theta_i = 0$, or $k_i^* = 3 - \frac{3}{2}\theta_i = 3 - \frac{3}{20} = 2.85$.

Total emissions are then $K^* = \sum_{i=1}^{N} k_i^* = 10 \cdot 2.85 = 28.5$.

(b) If we maximize global welfare, what level of carbon emissions should we choose for country i? What are total emissions?

Solution: The global FB will solve $2 - \frac{2}{3}k_i^{\text{FB}} - \sum_{i=1}^{N} \theta_i = 0$, or $k_i^{\text{FB}} = 3 - \frac{3}{2} = \frac{3}{2}$.

Total emissions are then $K^{\text{FB}} = \sum_{i=1}^{N} k_i^{\text{FB}} = 10 \cdot 1.5 = 15$.

(c) By how much does total climate damage increase or decrease in moving from the outcome in part (a) to the outcome in (b), if at all?

Solution: Damage under (a) is $\sum_{i=1}^{N} D_i(K) = \sum_{i=1}^{N} \theta_i \cdot 28.5$, or 28.5 since $N = 10$ and $\theta_i = \frac{1}{10}$.

Damage under (b) is $\sum_{i=1}^{N} D_i(K^{\text{FB}}) = \sum_{i=1}^{N} \theta_i \cdot 15$, or 15 since $N = 10$ and $\theta_i = \frac{1}{10}$.

Damages fall by $28.5 - 15$, or 13.5.

(d) Is moving from (a) to (b) a Pareto improvement?

Solution: Yes, by symmetry.

We can also verify that every country is better off: $2k_i^* - \frac{2}{3}(k_i^*)^2 - \theta_i K^* < 2k_i^{\text{FB}} - \frac{2}{3}(k_i^{\text{FB}})^2 - \theta_i K^{\text{FB}}$.

(e) If all N countries can contract costlessly with one another, have perfect information about θ_i for all i, and each maximize their payoffs, will they solve the climate change externality? Explain.

Solution: Yes, the Coase theorem applies!

(f) Do the assumptions in (e) seem realistic to you?

Solution: No. In particular, climate change does not seem to be solved yet, suggesting one or more of the assumptions of the Coase theorem do not hold for climate change.

(g) Now suppose $N = 4$, that the first two countries care a lot about climate change (so that $\theta_1 = \theta_2 = 1$), and that the remaining countries do not care about climate change (so that $\theta_3 = \theta_4 = 0$). If each country maximizes their individual payoff, what will be the global quantity of emissions? Are any countries worse off under the first-best?

Solution: The first two countries have $k_1^* = k_2^* = \frac{3}{2}(2 - \theta_i) = \frac{3}{2}$. The second two countries have $k_3^* = k_4^* = 3$. Total emissions is therefore $k_1^* + k_2^* + k_3^* + k_4^* = \frac{3}{2} + \frac{3}{2} + 3 + 3 = 9$.

Yes, countries 3 and 4 are worse off under the first-best because they derive no value from the emissions reductions, but are required to lower their emissions below k_3^* and k_4^* due to the externality they impose on countries 1 and 2.

QUESTION 3 (40 points). Elon Tusk.

Elon Tusk wants to sell us a solution to climate change for $1 trillion today.

Assume that climate change will destroy $100 trillion units of consumption in 2123.

(a) Using Ramsey's rule, calculate the net present discounted value from the viewpoint of 2023 of avoiding climate change if consumption will grow at rate $g = 2.5\%$, our elasticity of marginal utility with respect to consumption is $\theta = 2$, and our rate of pure time preference is $\rho = 0\%$.

Solution: Ramsey's rule gives us $r = \theta g + \rho = 0.025 \cdot 2 + 0 = 0.05$. The net present discounted climate damage is then $\frac{1}{(1+r)^{2123-2023}} \cdot 100 = 0.76$ or $760 billion.

(b) Based on your answer to (a), should we buy Elon Tusk's solution to climate change if we want to maximize welfare?

Solution: No. $1 trillion is greater than $760 billion. (Note that if we had the option to wait, we will eventually want to buy Tusk's solution, assuming it still costs $1 trillion, since as we get closer to 2123, the net present discounted climate damage will grow, eventually above $1 trillion.)

(c) Last Thursday (Nov 9), the US government finally released its new guidance for discounting in cost-benefit analysis. The government recommends a "descriptive" approach based on the real rate of return on government debt ($r = 2\%$). Calculate the net present discounted value of avoiding climate change using the government's new approach.

Solution: If $r = 0.02$, then $\frac{1}{(1+r)^{2123-2023}} \cdot 100 = 13.8$ trillion.

(d) If the government follows its discount rule in (c) and maximizes welfare, will it buy Elon Tusk's solution to climate change?

Solution: Yes. Note that if there are no other buyers of Elon Tusk's solution, this implies that he may have a strong incentive to contribute to the government's re-election campaign.

(e) Suppose that there is a chance that, during the next 100 years, someone other than Elon Tusk will discover a solution to climate change that will cost half as much as Elon's solution. Without doing any math, explain how this might change your answers to (b) and (d).

Solution: For (b), we still don't want Tusk's solution. If someone shows up with a solution that costs half as much, then we will want to buy it.

For (d), this could reverse our decision to buy from Tusk if the probability of discovery is sufficiently high. In that case, buying from Tusk is not desirable because destroys our option value from waiting for the lower-cost future solution, which—if the probability of discovery is sufficiently large—will exceed the value we attribute to Tusk's solution.