Economics 134 Fall 2025 Midterm 2

November 12, 2025

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 (30 points).

True or false:

(a) Gross domestic product (GDP) and carbon dioxide emissions are highly correlated across countries, implying that reducing carbon emissions will lower economic growth.

Solution: False; this fact does not imply that reducing emissions will lower economic growth. Correlation is not causation.

(b) Because the estimated damages from climate change are primarily concentrated in poor countries, large international transfers are likely necessary to make the world's first-best climate policy a Pareto improvement.

Solution: True.

(c) The big rainstorm coming tomorrow to Los Angeles could be an example of climate change.

Solution: False; it is an example of weather. The climate is permanent.

(d) Economists broadly agree that the real discount rate for cost-benefit analysis should be taken from the market, in order to account for the opportunity cost of capital.

Solution: False; economists do not "broadly agree" about what the discount rate should be or that the descriptive approach should be used over the prescriptive approach.

(e) Most climate scientists believe that doubling the current atmospheric concentration of carbon dioxide will increase the average global temperature by exactly 3°C.

Solution: False; there is significant uncertainty over this parameter.

(f) On average, facilities participating in the Los Angeles emissions trading program lowered their pollution by more than similar facilities regulated by command-and-control. However, the trading program led some places to experience relatively more pollution than with command-and-control.

Solution: True.

QUESTION 2 (60 points). The river.

There are N farms located on a river. Each farm can take q_i units of water from the river in order to produce q_i units of grain that it can sell for a farm-specific price p_i.

The more water taken by all of the farms, the more difficult it becomes for each farm to take water from the river. Specifically, taking q_i units of water costs

$$cq_i^2 + \theta \sum_{i=1}^{N} q_i,$$

where $\sum_{i=1}^{N} q_i$ is the aggregate withdrawal and $\theta > 0$. Assume $p_i > \theta N$ for all i.

(a) If each farm maximizes its own profits, given by

$$\pi_i(q) = p_i q - cq^2 - \theta \sum_{i=1}^{N} q_i,$$

what q_i^* will each firm i use (in terms of θ, p_i, and c)? Does your answer depend on N?

Solution: The first-order condition is $p_i - 2cq_i^* - \theta = 0$, or $q_i^* = \frac{p_i - \theta}{2c}$. The answer does not depend on N.

(b) Calculate the efficient (first-best) level of water use for each farm i (in terms of θ, p_i, and c). Does your answer depend on N?

Solution: The first-order condition is $p_i - 2cq_i^{\text{FB}} - N\theta = 0$ or $q_i^{\text{FB}} = \frac{p_i - N\theta}{2c}$. Yes, the answer depends on N.

(c) Suppose we require every farm to use the same $\overline{q}$ (and choose $\overline{q}$ to maximize social welfare). Will this lead to higher social welfare than the free market outcome in (a)? Briefly explain.

Solution: Yes; this is a command-and-control policy, but it should improve on the free market outcome for the reasons discussed in lecture. By restricting a bit of the water for the farm that consumes the greatest amount of water, we can increase welfare. (An exception is the case in which $N = 1$, in which the free market outcome is also efficient, but it is not necessary to mention this case to obtain full credit.)

(d) Will the uniform mandate $\overline{q}$ in (c) attain the efficient outcome? Briefly explain.

Solution: Only if $p_i = p$ for all i (or $N = 1$). Otherwise, we could do better by allowing trade in water rights across farms.

(e) Give an example of a policy discussed in lecture that will attain the efficient outcome.

Solution: A cap-and-trade that fixes the total quantity at $\sum_{i=1}^{N} q_i^{\text{FB}}$ and then allows farms to trade water rights will work. A per-unit tax equal to $(N-1)\theta$ will also work. If the farms merged into a single farm, this would also attain the efficient outcome.

(f) Is the river a public good? Explain.

Solution: No, because it is rivalrous.

(g) Suppose that instead of firms taking water from a river, each i was a country emitting carbon into the atmosphere. Briefly explain how your answers to (a) and (b) can be used to show that international coordination on climate change can be more valuable for the world as the number of countries increases.

Solution: Going from the free market in (a) to the first-best in (b) creates greater net benefits as N increases; we could take our answers to (a) and (b) and calculate the total payoffs, $\sum_i \pi_i(q_i^*)$ and $\sum_i \pi_i(q_i^{\mathrm{FB}})$, then show that the difference increases in N.

QUESTION 3 Climate change (45 points).

For parts (a)–(d), suppose that climate change will destroy \$1 trillion of consumption in 2100.

(a) Given a discount rate r, write down an equation that measures the net present discounted value of avoiding climate change (from the viewpoint of 2025).

Solution: $\frac{1}{(1+r)^{75}}$ trillion.

(b) Suppose that our elasticity of marginal utility is $\theta = 2$, our annual rate of pure time preference is $\rho = 0.1\%$, and that we expect consumption to grow by $g = 2\%$ per year. Use Ramsey's formula to calculate the implied annual real discount rate r.

Solution: $r = \rho + \theta g = 0.1\% + 2 \cdot 2\% = 4.1\%$.

(c) Now suppose that three-quarters of the software engineers that we had expected would be growing the economy are instead growing tulips. The economy is now expected to grow only at $g = 0.5\%$. How will this change your answer to (b)? Does this make us more or less willing to pay to avoid climate change today, relative to (b)?

Solution: $r = \rho + \theta g = 0.1\% + 2 \cdot 0.5\% = 1.1\%$. It makes us more willing to pay to avoid climate change, because the discount rate is lower and our formula in (a) is decreasing in r.

(d) Suppose that we can completely avoid climate change by investing \$10 billion per year in solar energy for every year until 2100. Write down an equation (as a function of r) that we could use to determine whether this investment is worthwhile (i.e., whether its net benefits are positive).

Solution: If $\frac{1}{(1+r)^{75}}$ trillion $> \sum_{t=0}^{2100-2025} \frac{10}{(1+r)^t}$ billion, then the investment is worthwhile.

(e) Finally, suppose that, in addition the \$1 trillion of lost consumption in 2100, there is also small chance (probability $p = \frac{1}{100}$) of a tipping point in the climate system that destroys an additional

\$8 trillion of consumption in 2100. If our utility function is $u(c) = \ln c$, what is the net benefit (in terms of expected net-present-discounted utility, not consumption) of avoiding all climate change? Assume that, without any climate change, consumption in 2100 will be \$100 trillion.

Solution: $(1+\rho)^{-75} \ln 100 - (1+\rho)^{-75} \left[\frac{1}{100} \ln 91 + \frac{99}{100} \ln 99\right]$. Note that we now use the rate of pure time preference, ρ, not r, since we are comparing utility, not consumption.