WRITTEN PRELIMINARY Ph.D. EXAMINATION

Department of Applied Economics

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Natural Resource and Environmental Economics

Instructions:

• Identify yourself by your code letter, not your name, on each question.
• Start each question’s answer at the top of a new page.
• Answer four of the six questions, including at least one of the first two questions.
• You have four hours to complete this examination.
I. Burning fossil fuels results in emissions of greenhouse gases that contribute to climate change. How damaging climate change will turn out to be is uncertain. Consider a two-period model where \(e_t\) is the emissions of greenhouse gases in period \(t\), \(t = 1, 2\). Let the benefits of using fossil fuels, written in terms of the emissions that result, be given by: \(U(e_t) = e_t - (e_t^2/2)\). Damages from climate change are a function of the stock of greenhouse gases at the end of period 2, denoted by \(X\), where \(X = e_1 + e_2\). The damage function from climate change is: \(D(X) = Z \cdot X^2/2\), \(Z\) is a random variable. Assume that the expected value of \(Z\) is equal to one: \(E(Z) = 1\). For simplicity, assume there is no discounting.

A. Suppose that we will learn about the true value of \(Z\) only after emissions levels are chosen in periods 1 and 2. Solve for the optimal choice of \(e_1\) and \(e_2\) in this case. How are the optimal choices affected by uncertainty about damages?

B. Now suppose that we will learn the true value of \(Z\) prior to making a choice about emissions. Further suppose that \(Z\) can take on values \(z = 1.5\) or \(z = 0.5\) with equal probability. What are the optimal choices of emissions for each realization of \(z\)?

C. Given that there is a 50% chance of each realization, how does the ex ante expected level of emissions found in part (b) compare with emissions in case (a)? How would each of these compare to the case where the value of \(Z\) is equal to 1 with certainty?

D. What is the value of information in learning about the true value of \(Z\) prior to choice of emissions in the case where \(z = 1.5\) or \(z = 0.5\) with equal probability?

E. Some environmentalists have argued that in the face of uncertainty, we should be “precautionary.” In the case of climate change, a precautionary policy would mean that we should emit fewer greenhouse gases for cases with greater uncertainty about future damages from climate change. Do your answers to earlier parts of this problem support a precautionary policy or not? Explain.

II. A renewable resource has a state equation given by: \(\dot{S}_t = g(S_t) - h_t\), where \(S_t\) is the stock of the resource at time \(t\), \(\dot{S}_t = (dS_t/dt)\), \(g(S_t)\) is the natural growth function, and \(h_t\) is the harvest of the resource at time \(t\). Assume that \(g(0) = g(K) = 0\), where \(K > 0\) is the natural carrying capacity of the resource, \(g(S_t) > 0\) for \(0 < S_t < K\), and \(g''(S_t) < 0\). Let \(U(h_t)\) be the utility function and assume that \(U''(h_t) > 0, U'''(h_t) < 0\). Let the constant discount rate be \(\delta\).

A. Write down the dynamic optimization problem where the objective is to maximize the present value of utility from harvest. Define the current value Hamiltonian for this problem.

B. Using the necessary conditions for an optimal path, construct a phase diagram for the optimal harvest path with harvest on the vertical axis and stock on the horizontal axis. Characterize the optimal steady-state harvest and stock size. How does the optimal steady-state compare to maximum sustained yield?

C. Suppose that you start at the optimal steady-state stock size for a given discount rate. Then suppose that the discount rate is increased. Describe the transition path to the new optimal steady-state and describe how the new steady-state compares to the old steady-state.
III. Consider an industry model of a non-renewable resource with a known backstop technology price $P_B$, a known amount of reserves $X_0$, a periodic demand curve of:

$$Q^D(t) = \frac{A}{P(t)},$$

and a common discount rate of $\tau$. The consumption of the non-renewable resource generates greenhouse gases, in contrast to the clean backstop technology.

A. Discuss the character of the equilibrium path that would arise from a competitive industry exploiting this fixed resource. What happens to prices, to production, to rents, and to the remaining stock?

B. Derive an expression that shows how long it will take for the industry to fully exhaust the resource base.

C. Now suppose that a technological breakthrough occurs that reduces the backstop price to $\lambda P_B$ with $\lambda < 1$. Policy makers are aware that the new technology will accelerate the production of the non-renewable resource, thus exacerbating greenhouse gas emissions. Their proposal is to implement a tax equal to $\tau$ per unit extracted, with the expectation that this will counteract the backstop technology price drop, and slow exhaustion. Derive and expression for the new time to exhaustion, under both the backstop technology price drop and the per unit tax.

D. Show how to determine a tax rate that exactly counteracts the backstop price drop so that the new time to exhaustion is the same as the old one in (b).

IV. PU chemical has been dumping its chemical by-products into the Long River for five decades and using groundwater as its source of water. Recently, the Daily Record published evidence that serious health effects have emerged among residents in River City who live along the Long River and depend upon the river for their drinking water. In addition, the paper reports that groundwater levels have been dropping in some rural areas. You have just started working for the mayor of River City and have been asked to brief the mayor on the city’s water problems. The mayor’s plan is to forbid PU Chemical from dumping ANY residuals into the Long River and to start using groundwater as a partial substitute.

A. Use your knowledge of resource economics to illustrate the costs to society of continuing to allow PU Chemical to pursue its profit maximizing pollution strategy.

B. Explain to the mayor why her proposal to eliminate all residuals PU dumps is probably not the best strategy. What is a better policy and what policy tools could be used to achieve an economic optimum level of dumping?

C. Should the mayor also be concerned about PU’s use of groundwater? If so, why? What should she do if you told her private pumping may exceed current recharge rates?

D. What market failure is likely to occur as groundwater extraction increases? How might this market failure be corrected for when it becomes serious? Why, in many countries, have they failed to correct for this market failure in groundwater use?
V. This problem concerns the measurement of welfare change. Consider a consumer of two goods, 
\(x_1\) and \(x_2\), who has quasi-linear utility \(U(x_1, x_2) = \beta x_1 + \ln x_2\), with \(\beta > 0\).

A. Derive the consumer’s hicksian and marshallian demand functions.

B. Fix \(\beta = 3\). If prices and income, denoted \(\psi = (p_1, p_2, m)\), are initially \(\psi^0 = (50, 1, 700)\) 
and change to \(\psi^t = (1, 1, 700)\), compute equivalent and compensating variation as well as 
their ratio: EV/CV.

C. It is well known that in some situations EV can become quite large, but CV is bounded. 
Thus, willingness to accept can be much larger than willingness to pay. The following is 
such a situation. For the consumer described in this problem, suppose that \(p_2^0 = p_2^t = 1\) 
and that income is fixed (that is, \(m^0 = m^t = m\), not necessarily at \(m = 700\). Let 
\(k = p_2^0/p_2^t\). (In part b. above, \(k = 50\)) Show that for any \(k\), \(EV/CV = k\).

VI. Two firms are the only sources of smog-creating ozone emissions in a localized airshed. Before 
controls are imposed, the firms emit \(e_1 = 150\) and \(e_2 = 450\) units of ozone respectively. The 
firms’ abatement cost functions are

\[
AC_1(q_1) = 20q_1 + \frac{q_1^2}{2} \quad \text{and} \quad AC_2(q_2) = 20q_2 + \frac{q_2^2}{4},
\]

where \(q_i\) is abatement by firm \(i\). A regulator has decided that emissions are too high. 
The regulator knows with certainty that the marginal benefits from aggregate abatement are 
\(MB(q) = 270 - q/2 + \epsilon\), where \(q = q_1 + q_2\) is aggregate abatement and \(\epsilon\) is a random variable 
with \(E(\epsilon) = 0\). The regulator’s goal is to choose a policy to maximize expected welfare,

\[
W = D \int [MB(q) - MAC(q, \epsilon)] dq,
\]

A. Find the socially optimal level of abatement.

B. Suppose that the regulator has decided to employ an emissions tax to achieve the optimal 
level of abatement. What should the tax be? How much tax revenue will the government 
collect?

C. Now suppose that the regulator has decided to employ a permit-trading scheme. The 
firms behave competitively in the permit market. How many permits should the regulator 
issue? What will be the equilibrium permit price? How should the permits be distributed 
among the two firms to achieve the social optimum?

D. Which instrument is to be preferred in this case? Support your answer carefully.