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**Take Home Exam 2**
Spring 2012

**Due by 5 pm on Wednesday 5/2 if submitted on paper or by midnight if sent by email.**
**Do not open this exam until you are ready to begin.**

## Instructions

1. Please write your answers on regular paper. You do NOT need to type your answers.

2. Write your **SUID** on your exam. Please **DO NOT** write your name.

3. There's no hard time limit but try to do it in one sitting of no more than about 3 hours.

4. Show all your work. Answers without supporting work will receive little or no credit.

5. The exam is "open book/open notes": you are welcome to refer to your notes, to the exercises and their answer sheets, or to readings listed on the syllabus.

6. It is NOT "open friend": you must do the exam yourself MAY NOT talk with anyone about it until after the due date.

7. Please do not use Google: you can use materials that you already have on hand but please don't go hunting for more.

8. Using a spreadsheet is OK as long as you attach a printout showing the details of your calculations. However, you should have no problem doing the exam with a calculator.

**Question 1: Multiple Source Pollution**

A regulator wants to reduce pollution from three firms. Each firm is currently emitting 4000 tons for a total of 12000. The marginal costs of abatement for the firms are given below, where each *Q* is the corresponding firm's quantity of abatement:

$$MCA_1 = (1/5) * Q_1$$
$$MCA_2 = (1/10) * Q_2$$
$$MCA_3 = (1/20) * Q_3$$

The marginal benefit of total abatement, $Q_T$, is given by $MBA = 1000 - (3/20) * Q_T$.

(1) Compute the efficient total amount of abatement and the amount that should be done by each firm. What is the total cost of abatement at this allocation?

(2) Suppose the regulator wishes to use an emissions tax to control the pollutant. What should the tax rate be? What will the total cost of the policy be to each firm, including both abatement costs and tax payments?

(3) Alternatively, suppose the regulator were to use a tradable permit policy. Please design a permit system that would achieve the efficient level of pollution while keeping total compliance costs (including revenue from permit trades) equal across the firms. What would the equilibrium permit price be? How many permits should be initially distributed to each firm?

(4) Now suppose that the permit system from (3) has been imposed but the marginal cost for firm 3 turns out to be different from what was expected. It's actually similar to firm 1:

$$MCA_3 = (1/5) * Q_3$$

Please determine the equilibrium price of a permit given the existing permit system. What is the efficient equilibrium? How large is the deadweight loss?

**Question 2: Effects of a Hybrid Policy**

A pollutant is currently uncontrolled and 1000 tons are being emitted. The marginal benefits and marginal costs of abatement are believed to be the following:

$$MBA = 700 - (2/3) * Q_a$$
$$MCA_e = 100 + (1/3) * Q_a$$

(1) Determine the efficient amount of abatement, the efficient amount of pollution, and the marginal cost and marginal benefit of abatement at that point provided that the curves above are correct.

The regulator would like to use a hybrid policy to control the pollutant and establishes a regime with the following features: (a) the initial quantity of permits distributed is equal to the efficient amount of pollution from part 1, and (b) the price of additional permits is set to the expected marginal cost from part 1.

(2) Suppose the actual marginal costs of abatement turn out to be higher than expected: $MCA_h = 200 + (1/3) * Q_a$. Please determine the equilibrium price of a permit and the number of extra permits purchased from the government, if any.

(3) Finally, now suppose that instead the actual marginal costs of abatement turn out to be lower than expected: $MCA_l = 50 + (1/3) * Q_a$. Please determine the equilibrium price of a permit and the number of extra permits purchased from the government, if any.

**Question 3: Exhaustible Resource with a Backstop**

Consider the allocation of an exhaustible resource across three generations. The following information is available about demand and MEC in the three periods:

| Period | Demand | MEC |
|---|---|---|
| 1 | W2P1 = 1000 – 2*Q1 | 400 |
| 2 | W2P2 = 1200 – 2*Q2 | 300 |
| 3 | W2P3 = 1400 – 2*Q3 | 200 |

Initially, there are 1000 units of the resource available. The interest rate between generations is 100%.

(1) Please calculate the equilibrium royalty, extraction cost, price and quantity that would occur in each period, and summarize your results in a table.

Now suppose that a backstop is available at a marginal cost of $480.

(2) Please calculate: the new equilibrium royalty, extraction cost, price and quantity in each period, summarizing your results in a second table. Finally, calculate the total amount of the resource produced via the backstop.

**Question 4: Risk Assessment**

In 2000, the US EPA updated its standards for arsenic in drinking water. The previous standard had been 50 micrograms per liter (µg/L) but new evidence indicated a stronger link between arsenic and various health problems, especially bladder and lung cancer. The following problem is loosely based on a risk assessment done at that time.

In revising the arsenic standard, EPA considered four alternatives: 20, 10, 5 and 3 µg/L. It was also aware that the concentration of arsenic varied around the country. Many water systems had very low arsenic and would have complied with any of the standards without installing new equipment. However, some communities had levels above 3 µg/L. To keep the problem simple, suppose that the communities above 3 µg/L could be grouped into four categories and had the specific levels of arsenic and populations listed below:

| Community type | Current level of arsenic in µg/L | Population in millions |
|---|---|---|
| A | 4 | 10 |
| B | 8 | 9 |
| C | 14 | 5 |
| D | 28 | 3 |

In addition, an individual's annual risk of developing a fatal case of cancer due to arsenic exposure is about $4\times10^{-}7$ (0.4 in a million) per µg/L in his or her water supply, and the dose response function is approximately linear. For example, an individual in a type-D community would have a $1.12\times10^{-}5$ (11.2 in a million) risk of cancer due to arsenic. Finally, in carrying out the calculations below, please use a VSL of $7 million (that's a little higher than EPA used at the time but the agency also accounted for morbidity).

(1) Please calculate the expected annual number of arsenic-induced cases of cancer in populations A through D prior to the change in the standard (that is, at the exposure levels listed above). You may assume throughout the problem that the communities above are the only ones exposed to arsenic.

(2) Now consider the proposed standards. Please compute the new expected number of cases of cancer under each of the proposed limits and also indicate the expected number of cases prevented. You should assume that only communities with existing arsenic levels above a new standard are affected, and that those communities install treatment equipment to meet the new standard exactly. For example, under the 20 µg/L standard, only type-D communities would be affected, and their exposure would drop to 20 µg/L.

(3) Finally, EPA estimated that the annual cost of achieving the new standards would have been the following: $77 million for 20 µg/L; $206 million for 10 µg/L; $472 million for 5 µg/L; and $792 million for 3 µg/L. Please note these are total costs from the existing standard and do not need to be added for policies focused on more restrictive levels (that is, the 10 µg/L standard costs $206 million, not $77+$206 million). Please compute the net benefits of each standard and indicate which one would be best.