EEP 101/ECON 125 Environmental Economics: Problem Set 3

*This handout includes the questions for Problem Set 3. Answers need to be turned in via bCourses, where you will be prompted to enter your answers. For most questions, you will just enter your answer. Questions marked with an asterisk * here will allow you to enter an explanation, and will be graded for partial credit.*

If you have numerical answers that are non-integers, report your answer rounded to the nearest tenth (one decimal). For example, report 1/3 as 0.3. This will help ensure that the computer recognizes all correct answers. If the problem instructs you to "think for yourself" it means I want you to think about this issue, but you are not required to upload an answer explaining your thoughts; just provide the numerical result.

Part I. Heterogeneity and gains from trade

If all polluters were identical, then a policy that requires the same thing of all polluters (i.e., a regulation) might be cost effective. Put differently, it is the differences across polluters (their heterogeneity) that makes market-based mechanism especially useful. This question uses our basic birthday abatement exercise setup to illustrate how heterogeneity impacts the gains from trade (the cost effectiveness of a cap-and-trade system).

There are 10 firms that each have 10 units of emissions. The only way to reduce emissions is through a direct abatement function that has marginal cost α for each firm, and each firm can abate a maximum of 10 units of emissions. (This is our standard setup.) Five of the firms are low cost, and five are high cost. In **Scenario 1**, the low cost firms have abatement cost $\alpha = 2$, and the high cost firms have $\alpha = 18$. In **Scenario 2**, the low cost firms have abatement cost $\alpha = 8$, and the high cost firms have $\alpha = 12$.

Across the two scenarios, the average cost of abatement is the same. What is different is that in Scenario 1, the variance (heterogeneity) is larger.

1. In Scenario 1, suppose that a government imposes a "fair" uniform regulation that requires each polluter to reduce emissions by 40%. (No trading is allowed.) What is the total amount of abatement that is achieved, and what is the total cost across all polluters of achieving this abatement? (1 point)

2. In Scenario 1, suppose instead that the government imposes a cap and trade system that reduces emissions by 40%. Abatement is the same as in the prior case, but cost should go down. What is the total cost of abatement in this case? (1 point)

3. Now suppose that Scenario 2 is true instead, and the government imposes the "fair" uniform regulation that requires each polluter to reduce emissions by 40% (no trading). What is the total cost of abatement in this case? Before calculating this, ask yourself what you expect to find! (1 point)

4. In Scenario 2, suppose instead that the government imposes a cap and trade system that reduces emissions by 40%. What is the total cost of abatement in this case? Before calculating this, ask yourself what you expect to find! (1 point)

5. In which Scenario are the gains from trade (i.e., the cost reduction from allowing trading) larger? Scenario 1 or Scenario 2? (1 point)

Part II. **Uncertainty and policy design**

The Weitzman model is our foundation for exploring the implications of uncertainty. This question asks you to explore some results related to policy intervention in the presence of uncertainty.

A town council wishes to reduce the pollution in its drinking water. The town draws drinking water from a river that is polluted by upstream farms and factories. A water filtration company can clean the water (at the town's expense). The company's marginal cost of abatement is equal to $4q$, where q is a measure of the abated pollution. The town knows the firm's abatement cost, but it does not know for sure the size of health benefits from abatement. Instead, they believe that the marginal health benefit per unit of abatement could be the five following values, each with the assigned chance:

$$MB = \begin{cases} \$2 & 20\% \\ 4 & 20\% \\ 7 & 10\% \\ 12 & 30\% \\ 20 & 20\% \end{cases} \tag{1}$$

6. If the town uses a price instrument (i.e., offers the water filtration company a subsidy per unit of abatement), what price should it set? (1 point)

7. If the town uses a quantity instrument (i.e., mandates a given quantity of abatement and then pays the firm its true cost), what quantity of abatement should it choose? (1 point)

8. True/false: Ex ante (meaning before we know which MB is correct), the town should prefer a tax because marginal cost is relatively steep compared to marginal benefits. Explain briefly. (* 1 point)

9. True/false: Suppose that it turns out that the true MB was 20. In that case, the town will wish it had chosen a tax, rather than a quantity regulation. Explain briefly. (* 1 point)

Now consider a new scenario. Suppose the town knows the marginal benefit of abatement is equal to $40 - 2q$. But, the town is unsure about the MC. There is a $1/3$ chance that the marginal cost is a constant $7 + q$, and there is a $2/3$ chance that the marginal cost is $19 + q$.

10. If the town uses a price instrument (i.e., offers the water filtration company a subsidy per unit of abatement), what price should it set? (1 point)

11. If the town uses a quantity instrument (i.e., mandates a given quantity of abatement and then pays the firm its true cost), what quantity of abatement should it choose? (1 point)

12. True/false: Ex ante (meaning before we know which MC is correct), the town should prefer a quantity regulation because marginal benefit is relatively steep compared to marginal cost. Explain briefly. (* 1 point)

13. Draw (and upload) a graph that shows the deadweight loss that results from uncertainty under a quantity policy and includes the two possible marginal cost functions and the marginal benefit function. (* 1 point)

14. In our class examples, the two deadweight loss triangles that are associated with a given policy (e.g., a tax policy) were the same size. Are your triangles the same size in each graph? Explain why or why not briefly. (* 1 point)

Part III. **Incidence**

This problem invites you to think work through an example of the incidence of a tax and the possibility of compensating for lost surplus through revenue reallocation.

Consider a market for a good X with the following equations. Total benefit is $100X - 0.5X^2$. Total cost is $2X^2$. The good has a total externality equal to $5X + 0.125X^2$.

15. What is the consumer surplus, producer surplus and total external damages in this market when there is no tax? (3 points)

16. Suppose that a corrective tax following the Pigouvian prescription is employed. What is that tax rate? (1 point)

17. What is the new consumer surplus, producer surplus, total externality and government revenue? Before you calculate your answers, inspect the supply and demand curves and try to predict which side of the market do you expect to bear a larger share of the burden of the tax. Then check your reasoning after you find the answers. (4 points)

18. Suppose that the damages from the externality were felt by the consumers in this market. How much revenue would need to be given to consumers to make them as well off as before the tax. How much revenue would need to be given to producers in order to make them just as well off as before the tax? (2 points)

Part IV. **The Diamond model**

19. There are 6 widget factories clustered into an industrial zone upwind of a city. Each factory emits 1 unit of particulate matter into the air for each widget it produces. These emissions travel to the city and cause harm to two groups of city residents. The first are school children, who receive $2 worth of damages for each unit of pollution. The second group are nursing home residents, who receive $5 worth of damages for each unit of pollution.

    True or False: The Diamond model indicates that if the government can place a uniform tax on each factory per unit of emissions, the resulting allocation will not be fully efficient (it will only be "second best") because the damages are heterogeneous. Explain briefly. (1 point)

    We introduced the Diamond model as a case where the Pigouvian prescription needs to be amended. This problem walks you through a closely related problem. In class, we motivated the model thinking about heterogeneous consumers, but here I ask you to think about two different firms.

    Two local mines, named Asscher and Oval, extract identical diamonds. Suppose that the mines are small operations and are therefore price takers in the global diamond market, where the price per unit is currently $50. The Asscher mine is located in a low population part of Napa County where the mine creates an externality by using up fresh water supplies. The private cost of Asscher extraction is equal to $MC_A = Q_A$, while the social damages from water use are equal to $MED_A = 1$. The Oval mine is located in Richmond, and the mine leaches chemicals into the Bay that cause significant problems. The private cost of Oval extraction is $MC_O = 4Q_O$ and the social damages from the chemical leakage is $MED_O = 2$.

20. Suppose that the Bay Area Social Planner could impose a per unit tax on Asscher, and a separate tax on Oval. What would be the tax on each? Call these the first-best mine-specific tax rates. (2 points)

21. Now, suppose instead that the Bay Area Social Planner must choose one tax rate that will apply to both mines. According to the model of Peter Diamond that we discussed in class, will the second-best tax be closer to the first-best mine-specific tax rate for Asscher, or the one for Oval? Explain why in one or two sentences.* (2 points)

22. What is the second-best tax rate on diamond extraction, assuming the tax rate must be the same for both mines? (2 points)

(Hint: One way to solve this is to maximize social welfare, which is tax revenue plus firm profits minus the externality. You can also apply the Diamond formula directly.)

23. Draw and upload two graphs that depicts the deadweight loss that results from imposing a uniform tax on the two mines. (Include one graph for each mine. You can draw them side by side and upload as one image.) Your graph should include the marginal benefit, marginal cost, marginal social cost, the second-best uniform tax, the quantity the firm will choose given that tax, and the socially optimal quantity. (4 points)