Environmental Economics: Problem Set 1
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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 dif ferences 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 zero emissions. (This is our standard setup.) Five of the firms are low cost, and five are high cost. In Scenario 1, low cost firms have abatement cost $\alpha_L = 2$, and the high cost firms have $\alpha_H = 18$. In Scenario 2, the low cost firms have abatement cost $\alpha_L = 8$, and the high cost firms have $\alpha_H = 12$.

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?

The total amount of pollutants emitted by firms is T :

$$T = 100 \text{ units}$$

and the total abatement is ΔT :

$$\Delta T = \eta T = 40 \text{ units}$$

The total cost across all the firms to achieve this abatement is TC :

$$TC = 5\,(4\alpha_L + 4\alpha_H) = 400$$

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?

Due to the fact that the low cost firms are cheaper to cope with the pollutants, all high cost firms have incentive to pay for the low cost firm to shoulder their abatement :

$$TC = \Delta T \times \alpha_L = 80$$

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!

It is expected to find the total cost TC shouldn't change, since the sum of the marginal cost to abate pollutants $(\alpha_L + \alpha_H)$ hasn't changed. It is still true that :

$$TC = 5\,(4\alpha_L + 4\alpha_H) = 400$$

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!

It is expected to find that the total cost will be lower, since in this cap-and-trade system the low cost firms will shoulder the responsibility of the abatement once they are paid by the high cost firms. So the total cost TC now is :

$$TC = \Delta T \times \alpha_L = 320$$

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

Apparently, the scenario 1 (the more heterogeneous one) enjoys more gains from the cap-and-trade motif.

Part II. Internalities

Internalities can significantly complicate the logic of the Pigouvian prescription. Often, when there is both an internality and an externality, an ex aggerated or attenuated Pigouvian tax can lead to efficiency, but only when the internality is homogeneous. When people differ in the mistake that they make, tax interventions will be second-best (and follow the logic of the Diamond model).

Moreover, different policies, not just direct pricing instruments (tax, or cap and trade), may be more efficient. What matters most in these situations is how well a given policy targets (has the most impact on) the agents who are making the mistake.

In this example, you consider how taxing fuel versus taxing a car can be used to overcome a bias in fuel economy valuation, and how the logic of "targeting" cited above determines which tool is better if there are some agents who are rational and others subject to undervaluation. But, to do this, you have to first understand how a bias in fuel economy can be represented in a familiar demand system.

In this example, consumers choose between a more efficient and less efficient automobile. The more efficient vehicle gets 30 miles per gallon (mpg) ($e_H = 30$), and the less efficient gets 25 mpg ($e_L = 25$). The demand for the more efficient vehicle is Q_H . ΔP is the price premium for the efficient car (e.g., how much more it costs than the less efficient car) in upfront cost, s is a subsidy the government provides for choosing the efficient car, LGS is the present-discounted lifetime gallons saved as compared to the cost of driving the less efficient vehicle, P_g is the price of gasoline per gallon, and t is a tax per gallon of gasoline. The product, LGS (P_g + t), is thus the lifetime fuel cost savings (FCS) of the vehicle.
(By definition LGS > 0, which means a positive number representing savings).

Gasoline consumption creates pollution and has a negative externality (MEC) equal to $1 per gallon. There is also a possibility of an internality. If $\vartheta = 1$, then the consumer is rational and values lifetime fuel costs (in present value) equally with upfront price. But, we allow for the possibility of undervaluation when $\vartheta < 1$, at which point the consumer trades-off upfront price against future fuel costs incorrectly.

What this problem is intended to show is that (a) either a subsidy for the clean car or an exaggerated tax on gasoline can correct an internality, but (b) these two policies create different distortions for a rational agent, and the subsidy for the new car is actually preferred.

To sum up:

$$e_H = 30 \ , \ e_L = 25 \ , \ \mathrm{MEC} = 1$$

$$Q_H = 50 - \frac{1}{100} [\Delta P - s - \vartheta \times FCS]$$

$$\Delta P = P_H - P_L$$

$$FCS = LGS \, (P_g + t)$$

ϑ is the "rational degree" of the consumers, while LGS is the present-discounted lifetime gallons saved as compared to the cost of driving the less efficient vehicle.

6. Suppose that a car lasts 10 years, and that users drive 7,500 miles per year. For simplicity, assume that the discount rate is 0, so the present discounted value of lifetime fuel costs is just the sum over 10 years. In that case, what is LGS?
(Hint: for each vehicle, calculate annual gallons required to drive 7500 miles per year by dividing by mpg and multiply by 10. The difference across the vehicles is the savings.)

$$\mathrm{LGS} = 10 \times 7500 \times (\frac{1}{e_L} - \frac{1}{e_H}) = 500$$

7. Suppose that the difference in prices is ΔP = 5, 000 and $P_g =$ $4 , and that both are fixed. What is the efficient quantity of vehicles to sell, Q*, in terms of θ, s, and t?

$$FCS = LGS\,(P_g + t) = 500 \times (4 + \mathrm{t}) = 2000 + 500t$$

So, the Q^* is :

$$Q^* = 50 - \frac{1}{100} [\Delta P - s - \vartheta \times FCS] = \frac{1}{100} s + 5\, \vartheta\, (4 + \mathrm{t})$$

8. If $\vartheta = 1$, consumers will choose the efficient quantity when we follow the Pigouvian prescription by adding a tax on gas equal to the externality; (i.e., if $\mathrm{t} = 1$, $\mathrm{s} = 0$.) Calculate this efficient quantity (when consumer is rational and tax & subsidy take care of the externality). Next, suppose that there is also an internality, so that $\vartheta = 0.75$. If $\mathrm{s} = 0$, what tax rate t* would cause consumers to choose the efficient quantity?
(The point of this is that we can exaggerate the Pigouvian prescription in order to correct both the internality and the externality. This will be efficient here because all consumers are assumed to have the same internality.)

For the rational consumers ($\vartheta = 1$) scenario, the tax equal to the MEC is added, so the efficient quantity Q^* is :

$$Q^* = \frac{1}{100} s + 5\, \vartheta\, (4 + \mathrm{t}) = 25$$

For the irrational consumers ($\vartheta = 0.75$) scenario, if any subsidy isn't attached to the purchase of high efficient car ($\mathrm{s} = 0$), let :

$$Q_H = \frac{1}{100} s + 5\, \vartheta\, (4 + \mathrm{t}^*) = Q^* = 25$$

we get :

$$\mathrm{t}^* = \frac{8}{3} > \mathrm{MEC}$$

and t^* is the tax we should exert on if we want to achieve the same equilibrium in the rational scenario. It is expected that t^* will be larger than the marginal cost of externality (MEC) due to the existence of the internality ϑ.