ECON4910 Environmental Economics — Seminar 2

February 10, 2015

Prices vs. Quantities Under Uncertainty

In this exercise we go through the core ideas of the classic paper "Prices vs. quantities" by Martin Weitzman (1974) from the reading list.[1] We will do this in a sequence of small tasks divided into a reasonable number of steps. Along the way, you will have to approximate social benefits and cost functions. Next, you need to explore about the best regulatory instrument under certainty and uncertainty. The central problem we have in mind is that a regulator has to choose a rule of pollution regulation and stick to it for sufficiently long period of time.[2] One rule is to name a price for pollution reduction and the other rule is to name the quota (quantity) of pollution reduction. The timing is as follows: First the regulator sets the value (of price or quota) and then economic agents undertake pollution reduction.

To begin with, suppose there is an economy with no regulation of pollution but the benevolent regulator of this economy would like to use market based instruments to address the pollution problem. The market based regulations we have in mind involve using a *price* firms have to pay for pollution or a *quantity* of emissions that firms are allowed to "produce". To be precise about our framework, suppose a given *society* has benefit of $B(q)$ and cost of $C(q)$ of q units of pollution reduction. The assumptions we impose on the cost and benefit functions are: $B'(q) > 0$, $B''(q) < 0$, $C'(q) > 0$, and $C''(q) > 0$.[3]

[1] Weitzman, M. L. (1974): "Prices vs. Quantities," *The Review of Economic Studies*, 41, 477–491

[2] Why not stick to rules for very short period of time or even why not allow regulators to have discretion? There are many reasons for choosing rules over discretion. Some have to do with dynamic incentives for investment and innovation that require predictability and maintaining greater predictability of the regulatory environment is more enhanced by rules than discretion. Some have to do with the potential for regulatory capture and corruption.

[3] Note that it is the social benefit and cost we are focusing on throughout this exercise even when it is not written explicitly. To make the interpretation of pollution regulation sensible, let us assume that society is composed of different parties and the party that benefits from the pollution reduction is different from the party that incurs the cost of pollution reduction.

Problem 1: Approximating the social benefit and cost functions.

(a) Begin from a situation of no pollution regulation, and use the second order Taylor approximation to estimate operational social benefit and cost functions.

(b) Next, determine the marginal benefit and marginal cost functions of pollution reduction. Specifically, if I write $\text{MB}(q) = \beta - bq$ and $\text{MC}(q) = a + cq$, then what are the values of $\beta, b, a,$ and c in terms of the parameters of your approximation in (a)?

Problem 2: Implementing socially optimal allocations under certainty

In this problem, we explore the socially optimal pollution reduction and its implementation with *price* and *quantity* instruments. To do this, we begin assuming that the planner knows the values β, b, a and c.

(a) What is the optimal amount of pollution reduction, i.e. q that maximizes the social welfare? Let's call this amount of pollution reduction q^*.

(b) To implement q^* using a quantity instrument, what should be the quota of q? Calculate the total welfare using the value of this quota.

(c) To implement q^* using a price instrument, what should the price of q be? Calculate the total welfare using the value of the price of q and compare the total welfare you found using the price instrument with the total welfare using the quantity instrument.

(d) Which instrument is better in terms of maximizing the social welfare?

Problem 3: Quantity regulation under uncertainty

In the following three problems, we explore the socially optimal pollution reduction and its implementation with *price* and *quantity* instruments assuming that the planner has imperfect knowledge about the values $\beta, b, a,$ and c.

To consider a simple case, suppose the planner knows the values of $\beta, b,$ and c but he is uncertain about the value of a, i.e. the social marginal cost of pollution reduction. More specifically, suppose the planner knows that $a = \gamma + \theta$ in which γ is known but θ is a random variable taking two values i.e. $+\delta$ and $-\delta$ with equal probability.

(a) For any *given* value of θ find the optimal amount of q and let's call this amount this value q^{**}.

(b) Do you think this optimal values is directly implementable with *price* or *quantity* instruments?

(c) Suppose the regulator sets a quota of $\bar{q}$. Show that the deadweight loss of this quota is $\frac{b+c}{2}[\bar{q} - q^{**}]^2$.

(d) In what sense is deadweight loss a welfare measure?

(e) Compute the deadweight loss for the cases of $\theta = +\delta$ and $\theta = -\delta$.

(f) Next, show that the expected deadweight loss (since θ is unknown) if the quantity $\bar{q}$ is imposed is $\frac{b+c}{2}[\frac{1}{2}(\bar{q} - \frac{\beta-\gamma+\delta}{c+b})^2 + \frac{1}{2}(\bar{q} - \frac{\beta-\gamma-\delta}{c+b})^2]$.

(g) Tell a brief story of why *expected* deadweight loss might be an appropriate welfare measure under uncertainty of the type the planner has.

(h) Show that the best quantity to impose *ex-ante* to minimize the *expected* deadweight loss is $\hat{q} = \frac{\beta-\gamma}{c+b}$ and provide an interpretation interns of *certainty-equivalent* cost.

(i) Show that the expected deadweight loss when $\hat{q}$ is imposed is $\hat{L}_q = \frac{1}{2}\frac{\delta^2}{c+b}$. For each parameter, provide economic intuition about how it is related to the expected deadweight loss.

Problem 4: Price regulation under uncertainty

Now, let's take a different policy instrument. Suppose the regulator names p per unit of q *before* the value of θ is realized. Firms, take the given p and maximize profits *after* the value of θ is realized.

(a) Show that the profit maximizing quantity response to the imposed price p is $q(p, \theta) = \frac{p-\gamma-\theta}{c}$.

(b) Next, show that the *expected* deadweight loss if price p is imposed before the value of θ is realized is $\frac{b+c}{2}[\frac{1}{2}(\frac{p-\gamma+\delta}{c} - \frac{\beta-\gamma+\delta}{c+b})^2 + \frac{1}{2}(\frac{p-\gamma-\delta}{c} - \frac{\beta-\gamma-\delta}{c+b})^2]$.

(c) Show that the price that minimizes the *expected* deadweight loss is $\hat{p} = \frac{c\beta+b\gamma}{c+b}$ and provide an economic interpretation in terms of certainty-equivalence noting that $\hat{p} = \beta - b\hat{q} = \gamma + c\hat{q}$.

(d) Show that, at the optimal *ex ante* price $\hat{p}$, the expected dead weight loss is $\hat{L}_p = \frac{1}{2}\frac{\delta^2}{c+b}[\frac{b}{c}]^2$. For each parameter, provide economic intuition about how it is related to the expected deadweight loss.

Problem 5: Price vs. Quantity

(a) Show that the *expected difference* in deadweight loss between the best-regulated *ex ante* quantity and the best regulated *ex ante* price is $\hat{L}_q - \hat{L}_p = \frac{\delta^2}{2c^2}[c - b]$. Which instrument is better for regulating pollution? Give an economic intuition behind the formula.

(b) Which situations *greatly* favor one instrument over the other, and for which situations does it not make such a great difference for welfare by choosing the wrong instrument choice?