

Second Challenge: Solutions
Environmental Economics: ECO 345
Fall 2011

Question 1 (9 points)

A small change in emissions resulting in large damages via a threshold implies marginal damages are steep. This favors permit regulation. Permit regulation fixes the total number of permits. If we set the number of permits small enough to ensure we do not cross the threshold, damages remain low. However, with a tax if marginal costs turn out to be high, many firms will pay the tax rather than reducing emissions. This can result in emissions crossing the threshold, causing very high damages.

Question 2 (18 points)

- a. Permits and emissions standards clearly fix emissions. Technology standards fix the technology and therefore emissions per unit, but not total emissions. The EPA is never sure how many CFL light bulbs people will buy, or how long the lights will stay on, for example. Pigouvian taxes do not fix emissions, as the EPA is never sure how many firms will pay the tax and how many will reduce emissions.
- b. Only Pigouvian taxes fix marginal costs, which are equal to the tax. As we saw, if the marginal compliance costs are high, permit prices and therefore marginal costs will rise. The same principle holds for emissions standards and technology standards.
- c. Pigouvian taxes and tradeable permits satisfy the equimarginal principle. With taxes, all firms set marginal costs equal to the tax and therefore the marginal cost of all firms are equal. Similarly, firms set the price of permits equal to marginal costs, and so marginal costs are equal across firms. Standards do not allow trade, and therefore marginal costs differ by firms.
- d. As shown in question (1), permits are best if marginal damages are steep.
- e. If marginal costs are steep, taxes are best since they allow the firm an “out” of paying the tax if reducing emissions gets too expensive.
- f. Taxes and tradeable permits are preferred, since they satisfy the equimarginal principle. Emissions standards are also preferred, since at least firms are allowed to reduce emissions in the least costly way.

Question 3 (8 points)

Safe harbor is equivalent to a technology or emissions standard. For example, if the firm is exempt from lawsuits by installing a particular piece of safety equipment, then we have a technology standard. Firms essentially must install the particular safety equipment, even if cheaper alternatives exist. Similarly, the Arizona law is a de facto emissions standard, since

all firms must essentially reduce emissions to the level which prevents lawsuits, even if some firms could reduce more cheaply than others. Thus safe harbor is not efficient.

Longer Questions

Question 4 (35 points)

a. We have:

$$e_1 = 4 - \frac{1}{2}MC, \quad (1)$$

$$e_2 = 3 - \frac{1}{2}MC, \quad (2)$$

$$e = 7 - MC. \quad (3)$$

$$MC = MD \rightarrow e = 7 - (1 + e), \quad (4)$$

$$e^* = 3. \quad (5)$$

Further,

$$t = MD = 1 + e^* = 1 + 3 = 4. \quad (6)$$

$$MC_1 = MC_2 = t = 4. \quad (7)$$

$$MC_1 = 4 = 8 - 2e_1 \rightarrow e_1 = 2, \quad (8)$$

$$MC_2 = 4 = 6 - 2e_2 \rightarrow e_2 = 1. \quad (9)$$

b. We have:

$$e_{1,0} = 4 - \frac{1}{2} \cdot 0 = 4, \quad (10)$$

$$e_{2,0} = 3 - \frac{1}{2} \cdot 0 = 3, \tag{11}$$

In the absence of regulation, firm one emits 4 and firm 2 emits 3. Compliance costs for the tax are then:

$$\text{Compliance costs} = CC_1 = \frac{1}{2} (4 - 2) 4 = 4, \tag{12}$$

$$\text{Compliance costs} = CC_2 = \frac{1}{2} (3 - 1) 4 = 4, \tag{13}$$

$$\text{Total compliance costs} = CC = CC_1 + CC_2 = 4 + 4 = 8, \tag{14}$$

c. We have:

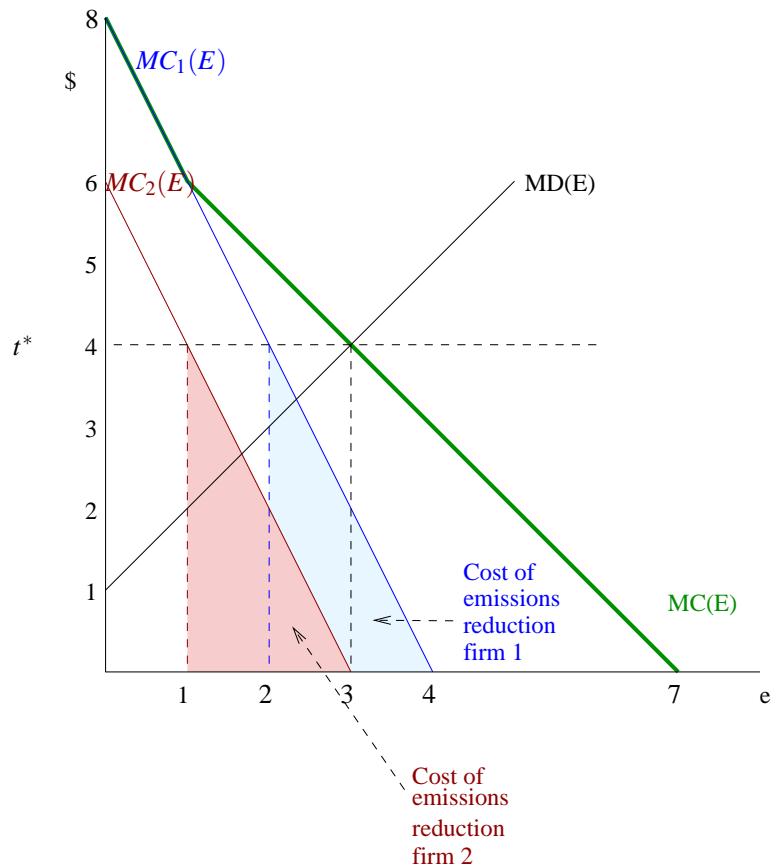


Figure 1: Pigouvian tax and compliance costs.

d. We have:

$$E_{\text{std}} = \frac{1}{2}E^* = \frac{1}{2}3 = \frac{3}{2}. \quad (15)$$

$$MC_1 = 8 - 2e_1 = 8 - 2 \cdot \frac{3}{2} = 5, \quad (16)$$

$$MC_2 = 6 - 2e_2 = 6 - 2 \cdot \frac{3}{2} = 3. \quad (17)$$

e. We have:

$$\text{Compliance costs} = CC_1 = \frac{1}{2} \left(4 - \frac{3}{2} \right) 5 = \frac{25}{4}, \quad (18)$$

$$\text{Compliance costs} = CC_2 = \frac{1}{2} \left(3 - \frac{3}{2} \right) 3 = \frac{9}{4}, \quad (19)$$

$$\text{Total compliance costs} = CC = CC_1 + CC_2 = \frac{25}{4} + \frac{9}{4} = \frac{34}{4} = \frac{17}{2} = 8.5, \quad (20)$$

f. We have:

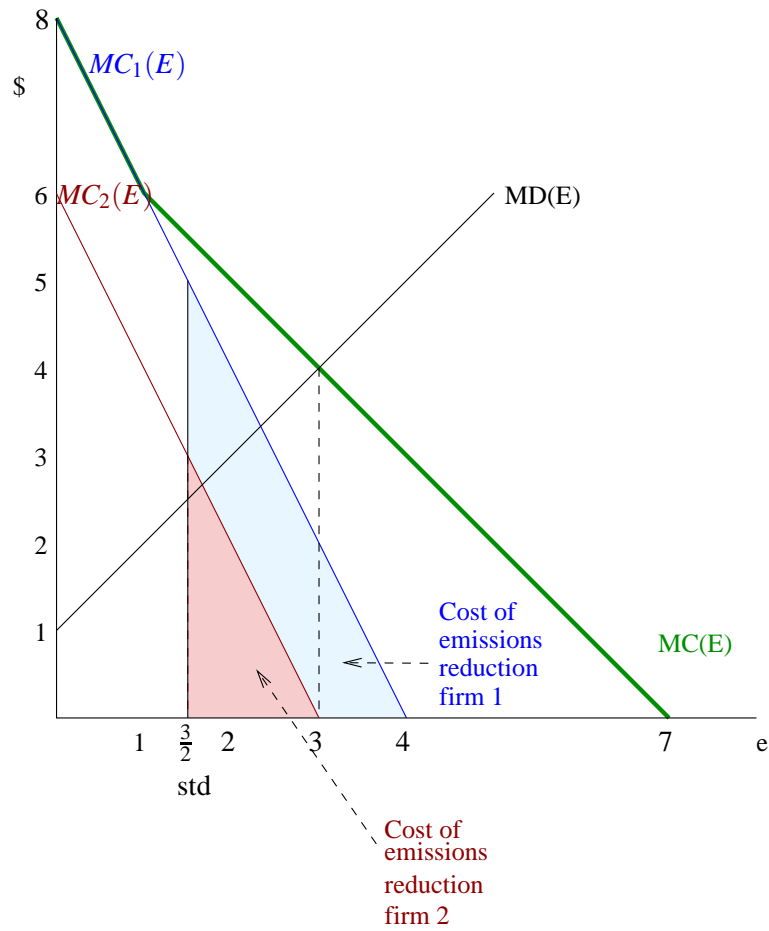


Figure 2: Emissions standard and compliance costs.

g. The standard has higher compliance costs. The standard does too much emissions reduction at the high cost firm (firm 1).

Question 5 (30 points)

a. We have:

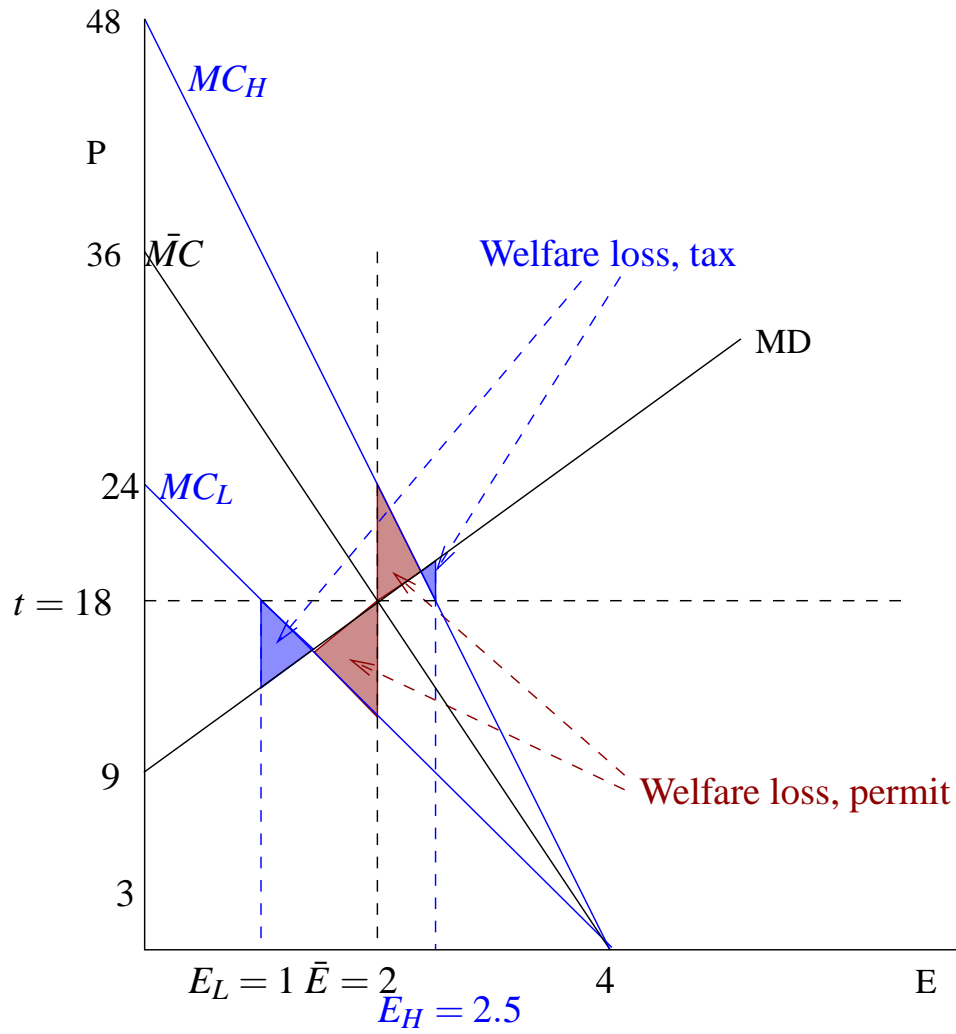


Figure 3: Marginal cost and damage curves, and welfare loss.

b. We have:

$$MC_L = (6 + 0)(4 - E) = 24 - 6E, \quad (21)$$

$$\bar{MC} = (6 + 3)(4 - E) = 36 - 9E, \quad (22)$$

$$MC = (6 + 6)(4 - E) = 48 - 12E. \quad (23)$$

Next we find the tax and marginal costs:

$$\bar{MC} = 36 - 9E = MD = 9E, \rightarrow E = 2, \quad (24)$$

$$t = MD = 9 \cdot 2 = 18. \quad (25)$$

$$t = 18 = MC_L = 24 - 6E_L, \rightarrow E_L = 1, \quad (26)$$

$$t = 18 = MC_H = 48 - 12E_H, \rightarrow E_H = \frac{5}{2}, \quad (27)$$

$$MD_L = 9 \cdot 1 = 9, \quad (28)$$

$$MD_H = 9 \cdot \frac{5}{2} = 22.5. \quad (29)$$

c. See the graph in part (a).

d. For tradable permits, from part (b), we set $\bar{E} = 2$ permits. Then:

$$MD = 9E = 9 \cdot 2 = 18, \quad (30)$$

$$MC_L = 24 - 6 \cdot 2 = 12, \quad (31)$$

$$MC_H = 48 - 12 \cdot 2 = 24. \quad (32)$$

e. First we need to calculate efficient emissions given perfect information:

$$MD = 9E = MC_L = 24 - 6E, \quad (33)$$

$$E_L^* = \frac{8}{5}. \quad (34)$$

$$MD = 9E = MC_H = 48 - 12E, \quad (35)$$

$$E_H^* = \frac{16}{7}. \quad (36)$$

We have:

$$\text{loss}_L = \frac{1}{2} (\bar{E} - E_L^*) (MD - MC_L) = \frac{1}{2} \left(2 - \frac{8}{5} \right) (18 - 12) = \frac{6}{5}, \quad (37)$$

$$\text{loss}_H = \frac{1}{2} (E_L^* - \bar{E}) (MC_H - MD) = \frac{1}{2} \left(\frac{16}{7} - 2 \right) (24 - 18) = \frac{6}{7}, \quad (38)$$

$$\text{Loss} = \frac{1}{2} \text{loss}_L + \frac{1}{2} \text{loss}_H = \frac{1}{2} \frac{6}{5} + \frac{1}{2} \frac{6}{7} = \frac{36}{35}. \quad (39)$$

- f. If marginal costs turn out to be high, taxes are better since the the slope of MC_H is greater than that of marginal damages ($12 > 9$). Conversely, if the marginal costs turn out to be low, permits are better since marginal damages are more steep ($9 > 6$).