Permit Trading In-Class Simulation
Environmental Economics

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1 Purpose

The purpose of this exercise is to allow students to experience how firms make emission-abatement tradeoff decisions in an environment with tradable emission permits and to see how tradable emission permits can function to achieve an efficient outcome.

2 Basics

- **Participants:** Each student will be assigned a number. The exercise assumes there is an even number of students. Each student represents a firm. The class is large enough that if there are and odd number of students on the day of the exercise it will not affect the calculations enough to matter.

- **Output market:** The firms operate in the same country. Each firm produces the same product, which is traded on a global scale. Production in the firms' home country is small relative to global production, so the firms take the market price of 40 for their output as given.

- **Production:** Firm i's production cost associated with Q_i units of output is $C(Q_i) = Q_i$ up to a capacity constraint of 20 (all firms have the same capacity constraint). Marginal cost is constant at 1.

- **Pollution:** Each unit of output produces one unit of pollution.
- **Pollution abatement:** A firm can reduce its emissions by investing in pollution abatement. For odd-numbered firms, the cost of reducing pollution by R_i units is $A_1(R) = 3R^2$. For even-numbered firms, the cost is $A_2(R) = R^2$. Thus, odd-numbered firms have relatively higher abatement costs than even-numbered firms. Marginal abatement costs are $6R$ for odd-numbered firms and $2R$ for even-numbered firms.

2.1 No regulation

To fix ideas, consider the case in which there is no environmental regulation. In the absence of environmental regulation, each firm chooses its output and pollution abatement to maximize its profit (reductions cannot exceed the total amount of pollution, which is Q_i, so it must be that $R_i \leq Q_i$):

$$\max_{Q_i \geq R_i} 40Q_i - Q_i - A_i(R_i).$$

Of course, in this case, the firm optimally chooses $R_i = 0$ and $Q_i = 20$, i.e., it does not invest in any pollution abatement and it operates at capacity. Profit is $(40 - 1)20 = 780$.

2.2 Emission cap

Suppose the government of the firms' home country institutes a cap on emissions of 10 units, with each unit of pollution in excess of this limit fined at a rate of 70/unit. Firm i's pollution associated with output Q_i is $Q_i - R_i$. To avoid the fine, firm i will choose Q_i and R_i such that $Q_i - R_i = 10$.[1]

Thus, firm i's profit maximization problem is:

$$\max_{Q_i} 40Q_i - Q_i - A_i(Q_i - 10),$$

which implies that for an odd-numbered firm,

$$40 - 1 - 6(Q_i^* - 10) = 0,$$

[1] Because the capacity constraint is 20, the maximum pollution abatement a firm would choose is $R_i = 10$. The marginal cost of abatement for an odd-numbered firm when $R_i = 10$ is 60, which is less than the fine of 70, so it is always optimal for the firms to abate rather than pay the fine.

which implies

$$Q_i^* = \frac{99}{6} = 16.50 \text{ and } R_i^* = 6.50.$$

Thus, odd-numbered firms reduce output below their unregulated levels. Profit is 516.75,[2] approximately one-third less than the unregulated profit. For even-numbered firms, it is optimal to produce at capacity and to invest in 10 units of abatement. Profit is 680 (even-numbered firms benefit from having lower abatement costs).

Intuitively, an additional unit of output requires an additional unit of pollution abatement, so a firm's total marginal cost is $C'(Q_i^*) + A_i'(Q_i^* - 10)$. A firm continues to increase output until it reaches the point where the output price is equal to this total marginal cost or until the firm reaches its capacity constraint.

2.3 Tradable permit exercise

- Consider a cap-and-trade policy whereby the government of the firms' home country issues tradable emission permits to the firms.
- Each firm is issued 10 permits. Each permit allows a firm to emit one unit of pollution.
- There will be a trading period during which firms can buy or sell permits. Prices may be any integer between 0 and 70. Trading quantities may be any positive integer—you cannot trade a fraction of a permit.
- Selling a permit counts as revenue and buying a permit counts as a cost.
- For each permit trade, firms must fill out a trading slip and bring it to the front. Slips must be dropped off at the front as soon as they are completed. Incomplete slips will be disregarded.
- At the end of the trading period, each firm must choose output Q_i and pollution abatement R_i (both non-negative integers). Once these are chosen, fill out the production report and turn it in before you leave the classroom.

[2] Profit is $40Q_i^* - Q_i^* - 3R_i^{*2}$.

- If a firm's emissions exceed its permits, it must pay the "safety valve charge" of 70 per unit of excess emissions.

Grading

- Your score in the exercise is based on your profit and a bonus for making at least one trade. To calculate your score, add the following:
  - *Operating profit*: $40Q_i - Q_i - A_i(R_i)$
  - *Trading profit*: revenue from sales of permits minus costs from purchases of permits
  - *Penalties*: minus cost of 70 for each unit of pollution in excess of the permits held at the end of the trading period
  - *Trading bonus*: add 10 points if you made at least one trade
- Your grade is equal to your score divided by a benchmark level of profit times 100. We will discuss the calculation of this benchmark after the exercise. The benchmark is different for odd-numbered and even-numbered firms.

3 Sample trading slip

Record of Permit Trade			
Time:			
Buyer #:		Buyer's Signature:	
Seller #:		Seller's Signature:	
Price Per Permit $:		# of Permits:	

4 Sample production report

Firm number	____
Name of student	____
Quantity produced	____
Permits on hand at end of trading	____
Abatement	____
Permits bought	____
Total paid	____
Permits sold	____
Total received	____
Trading profit or loss	____