Economic Instruments for Environmental Protection:

Illustrative Example

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The following hypothetical example illustrates some economic efficiency and equity issues related to various environmental regulation programs. Direct regulation (often called command-and-control) is compared with economic instruments, in particular, taxes and tradable permit programs.

Assume there is a lake called Lake Yunnan in southwest China that is undergoing severe anthropogenic eutrophication. Also assume there are two industries surrounding Lake Yunnan: a Fertilizer Factory and a Paper Mill. Each discharges 10 tons of phosphorus per year into the lake. The phosphorus abatement costs[1] for each industry are given in Table 1.

Through extensive research, the Yunnan Environmental Protection Bureau (YEPB) has found that the current phosphorus discharge from the Fertilizer Factory and the Paper Mill (20 ton P/year) is a leading cause of Lake Yunnan's worsening eutrophication. Additionally, the Bureau has found that if the cumulative load is lowered to a total of 10 tons of phosphorus per year, the eutrophication process will be reversed, hence protecting the lake as a source of drinking water and aquaculture. Therefore, the Bureau has decided to tighten the effluent regulations on the two industries to reduce the cumulative load by 10 tons per year. How can that be efficiently and equitably done?

Direct Regulation

Uniform Standards

One of the simplest ways of attaining the required load reduction would be to require both the Fertilizer Factory and Paper Mill to cut their loads by half. This form of direct regulation, known as uniform treatment, requires all polluters to meet the same standard. In this example, each industry would have to discharge no more than 5 ton P/ year. To meet these uniform standards, it will cost the Fertilizer Factory 16 million Yuan/yr to abate and the Paper Mill 73 million Yuan/yr. The total social cost would be 89 million Yuan/yr.

Table 1. Hypothetical Abatement Costs for Two Dischargers into Lake Yunnan

	Marginal Abatement Costs (10^6 Yuan/year)		Total Abatement Costs (10^6 Yuan/year)	
Discharge (ton P/year)	Fertilizer Factory	Paper Mill	Fertilizer Factory	Paper Mill
10	0	0	0	0
9	1	3	1	3
8	2	6	3	9
7	3	12	6	21
6	4	20	10	41
5	6	32	16	73
4	8	48	24	121
3	12	69	36	190
2	20	100	56	290
1	40	160	96	450
0	100	250	196	700

[1] In this example, abatement methods are not limited to traditional end-of-pipe treatment, but may include cleaner production, reductions in output, etc.

Fine-tuned Standards

Recognizing that each industry has different marginal abatement costs, the regulator can set fine-tuned standards such that, when the total load reduction is achieved, both polluters will be abating at the same marginal cost (a condition for optimality). Optimal fine-tuned standards in this example would be 3 ton P/yr for the Fertilizer Factory and 7 ton P/year for the Paper Mill. The respective abatement costs would be 36 and 21 Yuan/yr, giving a total social cost of 57 Yuan/yr. It is assumed that the regulator has perfect information about the costs of abatement at each industry.

Economic Instruments

Tax (Levy)

Instead of setting effluent standards, another option for the regulator is to set a tax on each ton of phosphorus discharged and let the two industries decided for themselves how much they abate. If the tax rate were set at 12 million Yuan/ton P, the Fertilizer Factory would reduce its pollution to 3 ton P/year, paying 36 million Yuan/yr in abatement cost and 36 million Yuan/yr in tax (3 tons P multiplied by 12 million Yuan/ton P) for a total cost of 72 million Yuan/yr. The Paper Mill would reduce its pollution to 7 ton P/year, paying 21 million Yuan/yr in abatement cost and 84 million Yuan/yr in tax (7 tons P multiplied by 12 million Yuan/ton P) for a total cost of 105 million Yuan/yr. It is assumed that the regulator has perfect information about the costs of abatement at each industry in order to set the optimal tax rate to stimulate the total 10 ton P/yr load reduction.

Subsidy

Similar to a tax, the government may offer a subsidy on each ton of phosphorus abated and let the two industries decided for themselves how much to abate. If the subsidy rate were set at 12 million Yuan/ton P, the Fertilizer Factory would reduce its pollution to 3 ton P/year, paying 36 million Yuan/yr in abatement cost and receiving 84 million Yuan/yr in subsidy (7 tons P abated multiplied by 12 million Yuan/ton P abated) for a total receipt of 48 million Yuan/yr. The Paper Mill would reduce its pollution to 7 ton P/year, paying 21 million Yuan/yr in abatement cost and receiving 36 million Yuan/yr in subsidy (3 tons P abated multiplied by 12 million Yuan/ton P abated) for a total receipt of 15 million Yuan/yr. It is assumed that the regulator has perfect information about the costs of abatement at each industry in order to set the optimal subsidy rate to stimulate the total 10 ton P/yr load reduction.

Tradable Permits

The regulator, recognizing that abatement information is asymmetric (available to the industries; not available to the regulator), can issue permits in the similar fashion to uniform standards, but let the two industries trade permits between themselves. For example, the regulator could give each industry 5 permits to discharge 1 ton P/yr. If the permits are tradable, and if the two companies can costlessly bargain with each other, then we can expect the Fertilizer Factory to sell 2 permits to the Paper Mill, thereby attaining the optimal phosphorus load distribution, *i.e.* the Fertilizer Factory will discharge 3 ton P/yr and the Paper Mill 7 ton P/yr. The respective abatement costs would be 36 and 21 Yuan/yr, giving a total social cost of 57 Yuan/yr. Importantly, the Fertilizer Factory will receive a gain from trade from the Paper Mill allowing it to carry out additional abatement.

Analysis

Which program should the Yunnan Environmental Protection Bureau choose? An analysis is given in Table 2. First, it must be noted that all programs will achieve the desired reduction of 10 tons per year of phosphorus to Lake Yunnan. Therefore the policy choice depends on three criteria: efficiency (total cost to society), equity (including political acceptability) and information availability.

In terms of efficiency, any program besides uniform standards is preferable. It is interesting to note, however, that the majority of environmental regulations are based on uniform standards.

Table 2. Evaluation of Policies in Illustrative Example

Policy	Discharge (ton P/yr)		Total Cost for each Industry (million Yuan/yr)		Total Social Cost (million Yuan/yr)	Efficiency	Equity and Political Acceptability
	Fertilizer Factory	Paper Mill	Fertilizer Factory	Paper Mill			
Uniform Standards	5	5	16	73	89	No	Mixed
Fine-tuned Standards	3	7	36	21	57	Yes	No
Tax	3	7	72	105	57	Yes	No
Subsidy	3	7	-48	-15	57	Yes	No
Tradable Permits	3	7	36 minus gain from trade	21 plus loss from trade	57	Yes	Yes

In terms of equity, uniform standards are often considered most equitable because they require each industry to achieve the same effluent load; yet, because of heterogeneous marginal abatement costs, the Paper Mill will pay much more than the Fertilizer Factory. This is not equitable and we can expect the Paper Mill to complain. The Paper Mill will certainly favor fine-tuned standards, but the Fertilizer Factory will most likely complain at the additional burden. After all, why should the Fertilizer Factory be penalized for having relatively inexpensive abatement costs? The tax program requires a large transfer of funds from both industries to the government and is unlikely to be politically acceptable with the industries. The subsidy program requires a large transfer of funds from the government to the industries and is unlikely to be supported by taxpayers. The tradable permit program is probably most acceptable to all groups. The gains from trade (32 million Yuan/year) will be distributed between the Fertilizer Factory and the Paper Mill according to how well each can bargain over the price of the permits: each will end up paying less than under the uniform standards (they would not trade if they did not have anything to gain). Provided the permits are initially distributed for free, as in the direct regulation approaches, there are no financial transfers between the government and the industries further increasing the political acceptability of the program.

Finally, the regulator will need complete information about the marginal abatement costs at each industry to implement fine-tuned standards, tax or subsidy. Because such cost information is unlikely to be willingly shared by the industries with the government, these three programs may not result in efficient outcomes. Both uniform standards and tradable permits require no information on marginal abatement costs.

Overall, on the basis of efficiency, equity, and information requirements, tradable permits appear to be the best choice for the regulator in this case. Nevertheless, there are several difficulties with implementing a tradable permit program that may make it less attractive for the regulator.