The Pollution Game: A Classroom Demonstration

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Abstract

Students in undergraduate environmental economics courses learn that while pollution creates a negative externality, governments can employ a variety of policies in order to achieve economic efficiency, such as command-and-control, emissions charges, or tradable emissions permits. However, little time is generally devoted to discussing the relative strengths of these policy options. This classroom demonstration is designed to illustrate the efficiency gains that can arise from various government policies aimed at internalizing negative externalities, as well as problems that arise due to heterogeneous abatement costs, asymmetric information, and strategic behavior on the part of the regulated firms.

The class is initially divided into three groups: the government regulatory agency, Ace Energy, and Deuce Petrochemical. The regulatory agency's task is to reduce pollution to the efficient level while minimizing the costs imposed on industry. The firms are motivated to minimize total abatement costs. Each firm's abatement cost is private information.

In successive rounds, regulators, in communication with firms free to respond strategically, design and implement a uniform standard for all firms, a system of emissions fees, and a cap-and-trade framework.

Students learn several important lessons during this fifty-minute demonstration. The first is that while all three regulatory strategies are efficient in theory, each presents unique challenges in implementation. For example, while the conventional command-and-control framework is likely to achieve its overall abatement goal, it is unlikely to do so efficiently in the presence of heterogeneous firms and asymmetric information. And while emissions fees are likely to equate the marginal cost of abatement across firms, they are not guaranteed to achieve the efficient level of abatement.

Because of its interactive nature, exercises like this one allow students to uncover these subtle concepts for themselves without having to rely on the jargon and abstraction that, while important to the study of economics, can put some concepts out of reach of undergraduate students. For example, during the demonstration's cap-and-trade round, intrepid students may try to corner the market for tradable permits, thereby driving their opponent out of business. Others may realize that their behavior in response to early regulations reveals information about their abatement cost schedule, introducing an incentive for firms to adapt their behavior to the dynamic nature of the demonstration.

The class as a whole may find that in an uncertain world where the marginal benefit of abatement is relatively flat while the marginal cost increase rapidly, a well designed emissions tax will tend to outperform a similarly well designed cap-and-trade scheme (McKibbin and Wilcoxen 2002).

While other games have been developed to show how various policies can be used to internalize negative externalities (e.g., Bergstrom and Miller 2000, Hazlett and Bakkensen 2005), none, to my knowledge, have been designed specifically to highlight the disparate regulatory challenges different internalization strategies present.

The poster will present a summary of the motivations for this classroom demonstration, the instructions for the game, a representation of the abatement cost schedules for the two firms, plausible student responses for the three regulatory rounds, and topics for discussion after completion of the demonstration.

Works Cited:

Bergstrom, Theodore and John Miller. 1997. *Experiments with Economic Principles*. McGraw Hill: San Francisco.

Hazlett, Denise and Laura Bakkensen. 2005. "Global Trade in CO_2 Permits: A Classroom Experiment." *Perspectives on Economic Education Research* 1:18-43.

McKibbin, Warwick and Peter Wilcoxen. 2002. "The Role of Economics in Climate Change Policy." *Journal of Economic Perspectives* 16:107-29.

The Government

In everything you do, your goal is to maximize society's well-being. The problem in front of you right now is the regulation of air pollution generated by the aluminum industry. While aluminum cannot be produced without also generating some amount of air pollution, the quantity of pollution can be controlled using any number of techniques (for example, by using inputs more efficiently or by installing abatement equipment). According to your crack staff of environmental toxicologists, engineers, and economists, your best guess as to the maximum quantity of air pollution that can be emitted without posing any risk to human health is 30 million tons per year.

You'll want to find some way to motivate the aluminum industry to limit air pollution to just 30 million tons (they're currently emitting twice that much). The hard part is determining how to go about motivating them. Remember that you're interested in society's wellbeing, which includes the wellbeing of polluting firms. So when you're devising your pollution-control strategy, you'd like to find some way to arrive at the efficient level of pollution while imposing the lowest possible costs on aluminum producers.

The following table shows the estimated damages associated with various levels of air pollution:

Tons of Pollution (in millions)	Total Damage (per year)	Tons of Pollution (in millions)	Total Damage (per year)	Tons of Pollution (in millions)	Total Damage (per year)
1	$0	21	$0	41	$660
2	$0	22	$0	42	$780
3	$0	23	$0	43	$910
4	$0	24	$0	44	$1050
5	$0	25	$0	45	$1200
6	$0	26	$0	46	$1360
7	$0	27	$0	47	$1530
8	$0	28	$0	48	$1710
9	$0	29	$0	49	$1900
10	$0	30	$0	50	$2100
11	$0	31	$10	51	$2310
12	$0	32	$30	52	$2530
13	$0	33	$60	53	$2760
14	$0	34	$100	54	$3000
15	$0	35	$150	55	$3250
16	$0	36	$210	56	$3510
17	$0	37	$280	57	$3780
18	$0	38	$360	58	$4060
19	$0	39	$450	59	$4350
20	$0	40	$550	60	$4650

Ace Energy

Your goal at Ace is really, really simple. You want to maximize profits. You don't care about trees or flowers or dolphins or anything else. All you want to do is to make the most money you possibly can. On the way to achieving that goal, you want to spend as little as possible on pollution abatement.

Left on your own, you'd generate 30 million tons of air pollution every year, though you can reduce that amount by pursuing costly abatement. Your pollution abatement costs are:

Tons of Pollution Abated (in millions)	Marginal Abatement Cost (per year)	Total Abatement Cost (per year)
1	$2	$2
2	$4	$6
3	$6	$12
4	$8	$20
5	$10	$30
6	$12	$42
7	$14	$56
8	$16	$72
9	$18	$90
10	$20	$110
11	$22	$132
12	$24	$156
13	$26	$182
14	$28	$210
15	$30	$240
16	$32	$272
17	$34	$306
18	$36	$342
19	$38	$380
20	$40	$420
21	$42	$462
22	$44	$506
23	$46	$552
24	$48	$600
25	$50	$650
26	$52	$702
27	$54	$756
28	$56	$812
29	$58	$870
30	∞	∞

Deuce Petrochemical

Your goal at Deuce is really, really simple. You want to maximize profits. You don't care about trees or flowers or dolphins or anything else. All you want to do is to make the most money you possibly can. On the way to achieving that goal, you want to spend as little as possible on pollution abatement.

Left on your own, you'd generate 30 million tons of air pollution every year, though you can reduce that amount by pursuing costly abatement. Your pollution abatement costs are:

Tons of Pollution Abated (in millions)	Marginal Abatement Cost (per year)	Total Abatement Cost (per year)
1	$4	$4
2	$8	$12
3	$12	$24
4	$16	$40
5	$20	$60
6	$24	$84
7	$28	$112
8	$32	$144
9	$36	$180
10	$40	$220
11	$44	$264
12	$48	$312
13	$52	$364
14	$56	$420
15	$60	$480
16	$64	$544
17	$68	$612
18	$72	$684
19	$76	$760
20	$80	$840
21	$84	$924
22	$88	$1,012
23	$92	$1,104
24	$96	$1,200
25	$100	$1,300
26	$104	$1,404
27	$108	$1,512
28	$112	$1,624
29	$116	$1,740
30	∞	∞

Ace Aluminum (Round 2)

Now suppose the EPA discovers that one of the byproducts associated with your pollution abatement technology is linked with a certain type of cancer. As a result, you have to start using a new, much more expensive technology.

Your new pollution abatement costs are:

Tons of Pollution Abated (in millions)	New Marginal Abatement Cost (per year)	New Total Abatement Cost (per year)
1	$8	$8
2	$24	$32
3	$48	$80
4	$80	$160
5	$120	$280
6	$168	$448
7	$224	$672
8	$288	$960
9	$360	$1,320
10	$440	$1,760
11	$528	$2,288
12	$624	$2,912
13	$728	$3,640
14	$840	$4,480
15	$960	$5,440
16	$1,088	$6,528
17	$1,224	$7,752
18	$1,368	$9,120
19	$1,520	$10,640
20	$1,680	$12,320
21	$1,848	$14,168
22	$2,024	$16,192
23	$2,208	$18,400
24	$2,400	$20,800
25	$2,600	$23,400
26	$2,808	$26,208
27	$3,024	$29,232
28	$3,248	$32,480
29	$3,480	$35,960
30	∞	∞

Deuce Petrochemical (Round 2)

Now suppose the EPA discovers that one of the byproducts associated with your pollution abatement technology is linked with a certain type of cancer. As a result, you have to start using a new, much more expensive technology.

Your new pollution abatement costs are:

Tons of Pollution Abated (in millions)	New Marginal Abatement Cost (per year)	New Total Abatement Cost (per year)
1	$2	$2
2	$6	$8
3	$12	$20
4	$20	$40
5	$30	$70
6	$42	$112
7	$56	$168
8	$72	$240
9	$90	$330
10	$110	$440
11	$132	$572
12	$156	$728
13	$182	$910
14	$210	$1,120
15	$240	$1,360
16	$272	$1,632
17	$306	$1,938
18	$342	$2,280
19	$380	$2,660
20	$420	$3,080
21	$462	$3,542
22	$506	$4,048
23	$552	$4,600
24	$600	$5,200
25	$650	$5,850
26	$702	$6,552
27	$756	$7,308
28	$812	$8,120
29	$870	$8,990
30	∞	∞