TEACHING TOOLS:

A POLLUTION RIGHTS TRADING GAME

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This article describes a classroom game in which students simulate the U.S. EPA's market for emission allowances to understand the efficiency benefits of market-based incentives for pollution control. It can be used in either a principles or environmental economics course. Acting as managers of coal-fired power plants facing different clean-up costs, students compare the cost of pollution reduction to the cost of acquiring permits to emit pollution. The game can be conducted in one 50-minute class period with discussion of the results carried over to the next class. (*JEL* A2)

I. OVERVIEW

The U.S. Environmental Protection Agency (EPA) in recent years has moved toward market-based incentives as an alternative to command-and-control measures to achieve pollution reduction. A limited pollution rights market has existed since 1976, but a higher level of activity is occurring in response to Title IV of the 1990 Clean Air Act Amendments (Field [1994]). Beginning in 1995, fossil fuel power plants nationwide have been forced to cut sulfur dioxide (SO2) emissions by 40% through market incentives provided by the EPA (Passell [1992] and Taylor [1992]). The goal is to allow the industry to choose least-cost emission reduction rather than using across-the-board mandates that limit emissions or require specific technology.

A classroom game can be played that allows students to determine the best choice among alternatives for meeting a regulatory goal of reduced emissions. Acting as the managers of several disparate industries, students can compare the cost of pollution reduction to the cost of acquiring permits to pollute. The appeal of the game is that students often have trouble accepting the concept of pollution rights but have no trouble using market forces to allocate them efficiently.

Incentive-based pollution allocations have been allowed by the EPA and state environmental regulators for years.[1] The most well-known and market-oriented example is the RECLAIM (Regional Clean Air Incentives Market) program in Southern California. The South Coast Air Quality Management District (AQMD) has operated a market for hydrocarbon and nitrogen oxide emissions since the beginning of 1994. Under the program, eligible industrial plants regulated by the AQMD are allocated a specific number of annual emission credits, each equivalent to one pound of pollution. The industrial plants are entitled to retain their credits, or sell them in return for finding a way to reduce their emissions to the allowable level. The credits may be purchased by other industrial plants to allow them to meet their emission limits without reducing emissions, or may be purchased by third parties, including environmental groups. The number of credits is scheduled to decline by 6%–8% each year for the next decade.

II. MATERIALS NEEDED

The classroom experiment operates in the same manner as the RECLAIM program, with

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1. Field [1994] describes examples including EPA's limited program in the northeastern U.S. dealing with power plant sulfur dioxide emissions contributing to acid rain, Wisconsin's tradable water discharge permits, and an Illinois program for trading nitrogen oxide. In a preview of coming developments, the Chicago Board of Trade is establishing a futures market in sulfur dioxide and other emissions that could eventually provide breadth and depth in the pollution rights market.

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several simplifications. The materials needed are a chart for each industry in the market to assist students in calculating the costs of alternative approaches,[2] certificates representing emission credits, and a regulator (usually the instructor) to control the number and initial distribution of credits. If the game is run through an auction market, the regulator must also run the auction.

I prefer to allow a decentralized market among the classroom industries in order to emphasize that the choice of an efficient solution is made without direction or coercion. I find that it takes about 45 minutes to introduce the game and conduct several rounds of trading. The students then need a little time to complete their worksheets. This means discussion must be postponed until the next class period unless you have two-hour classes, as I do. I don't believe there would be a serious loss of continuity when conducting discussion after a break of a couple of days if students have completed their worksheets.

III. INSTRUCTIONS FOR CONDUCTING POLLUTION RIGHTS TRADING GAME

Begin by discussing with students the concepts of regulatory control over air emissions and differences between command-and-control and market-based incentive methods of regulating. The key ideas for the students to consider are the regulatory agency's goal of reducing polluting emissions and the companies' goal of minimizing the costs of any pollution reduction they are forced to make. The attractive feature of the tradable emission rights method, compared to command and control, is that both goals can be achieved at a lower opportunity cost to society. The appeal of the game is that students can realize this condition by simulating the decision process in a simple classroom exercise.

The game is motivated by dividing the class into several small groups which allows several industries or plants to be established. In order for emission permits to be profitably traded, eligible companies or plants must face different costs of pollution abatement. This can be done either by creating in the classroom different industries each emitting a selected pollutant, or by providing plants within the same industry that use different production technology.[3] In the latter case you can create plants of various vintages each operating with a different cost structure. I present here the simpler approach using the same industry/different vintage plants.[4]

Each small group in the classroom (two students per group is a minimum number that allows a "manager" and "trader" for each company) represents a company within an industry that is emitting a specific pollutant. I use only one type of pollutant for simplicity. Each company faces a different schedule of pollution abatement costs, based on its product and technology. Again for simplicity, I use a constant marginal cost of abatement schedule. In more advanced classes, the marginal cost of abatement could be rising as emissions are reduced. Finally, each company is given a simple formula relating profit levels to output.

In the first stage of the exercise, small groups complete Table I (see Appendix I) for their respective companies. In this stage, students recognize the relationship between their emissions and output levels, and their output and profit levels. Using these simple linear relationships, they calculate their company's total current emissions and current profits. Each company is producing some pollution in the production process. Students can recognize that pollution reduction will not be obtained in a costless manner. They should be able to remember (or can be reminded) that if firms are already profit-maximizing, then pollution abatement will impose costs, and it is their responsibility to achieve it in the least-cost manner. This condition is combined in the next stage with differing costs of cleanup to create the opportunity for profitable trades among the companies.

2. I have included a table with the answers filled in as well as a blank version of the table for the students to complete.

3. The advantage of providing several different polluting industries is to emphasize the fact that even apparently "clean" industries do pollute, and that society benefits from emission reduction regardless of the specific identity of the polluter. The drawback is loss of simplicity and the greater time required. My version of this approach is presented in *Classroom Experiments: A User's Guide*, John Neral and Greg Delemeester, eds., Houghton-Mifflin, 1995.

4. This exercise ignores other real-world complications, such as assessing differential benefits of clean-up within and outside non-attainment areas, use of bubbles, etc. as discussed in Tietenberg [1985] and Carlson and Sholtz [1993].

Stage two begins with the regulatory agency (the instructor) imposing an emissions limit. I have chosen a reduction of emissions by 50% overall. The purpose of this limit is simply to show the overall amount of emissions reduction sought by the regulator. The initial allocation of pollution rights is an important equity issue in real-life regulatory discussions but, beyond discussing this with students afterwards, I avoid the issue in this exercise. Thus, the 50% emissions reduction is imposed on each firm which will reveal to each student group the amount of emissions reduction they must achieve. The environmental regulator (you) distributes a predetermined number of emission permits equally to the companies as indicated in the tables below. (It would be useful to have one-ton and 50-ton permits available for the two exercises below, respectively.)

Compliance can be accomplished in a variety of ways, and each group of students should now complete Table II for their company. This exercise requires the company groups to calculate the costs of available options. In the example, coal power plants face differing cleanup costs. Their choices are to install cleaning equipment, reduce output (and thereby associated emissions), or acquire sufficient pollution rights. Once the costs of choosing each of these compliance methods are evident, students will determine their company's optimal decision and permit trading can begin. The students are given a limited amount of time to balance their actual emission levels with their allowable emission levels. They will seek to achieve the required emissions level in the least-cost way. If they do not meet their mandatory limit, the environmental regulator will shut them down and they will lose all profits (or suffer losses equal to fixed costs) in the next time period.

An equilibrium price will be established for the pollution rights. Depending on how much time students have for trading (and the initial conditions), there may be some dispersion in transactions prices as it takes some practice for them to become savvy market participants. In order to allow students to learn the concept well, and to allow for some of the extensions described below, I usually run several permit trading sessions before extensive discussion of the results.

IV. WHAT TO EXPECT

Different Plants in the Same Industry

This form of the game assumes three coal-burning power plants in a competitive market situation with equal output, equal profit, and equal emissions. The difference among them is that the oldest plant faces lower costs of pollution abatement, and the newest plant faces higher costs of abatement than the medium-age plant. This example illustrates to students that the key ingredient for profitable emissions trading is varying costs of cleanup among firms, generally due to technology differences. Table I and Table II are provided in the appendix for ease in setting up the game.

Entries in italics in the tables are answers the students are required to calculate. I have included a version of that table with blank cells to be used as the handout for class.

In stage 1, students will calculate that each coal plant produces 200 tons of emissions and makes $10,000 per year in profits. They will be told in stage 2 that overall they must reduce emissions by 50% and they are each given pollution permits for 100 tons of emissions. They will then complete the remainder of Table II, calculating the costs of meeting their requirement by installing clean-up technology at the indicated cost, reducing output levels at the associated cost of lost profits, buying additional pollution permits from their competitors, or some combination of those choices. As indicated above, students will engage in permit trading after determining the costs of their options. It should be emphasized that they must have a permit for each ton of emissions at the end of the trading session.

Students should find that Coal Plant #1, the older plant with the lowest cleanup costs, will choose to sell its allocation of 100 tons of pollution rights and clean up all 200 tons it emits. Coal plant #2 of medium vintage will clean 100 tons of emissions and keep its quota of 100 tons of emissions. Coal plant #3 faces high cleanup costs and will instead purchase the 100 tons of emissions permits for sale by plant #1. Each of these choices will be cost-minimizing for the coal plants.

The exact cost to each plant of these decisions will depend on the price determined in the market for the emission permits. If students find the equilibrium price (which they should relatively easily in this version), the permits will sell for $20/ton. This will leave coal plant #1 in the advantageous position of zero net costs of compliance as it will sell 100 permits for a gain of $2000 and clean-up 200 tons of emissions for a cost of $2000. Coal plant #2 will be indifferent between buying and selling permits at a price of $20/ton as this is equal to its cost of cleanup; therefore, we expect it to retain its 100 tons of emission permits and perform cleanup to reduce total emissions to that level at a cost of $2000 total. Finally, coal plant #3 will face cleanup costs of $6000 and will opt instead to retain its original allocation of permits and purchase an additional 100 tons of permits from coal plant #1 at a cost of $2000. The expected results of the trading process are listed on Table II in the row labeled "Best Choice."

After performing the trading scenario(s) students will be ready to address the list of questions in Appendix II and discuss their findings.

Extensions and Complications

Extensions of the game can be easily performed. The easiest way to extend the game to illustrate additional concepts appropriate for a principles level class is to manipulate demand and supply variables affecting the permits. In a second round of allocations and trading, the regulator (you) can remove some pollution rights from the market or allow an environmental organization to enter the market and purchase them. Trading will result in a higher price for pollution rights than in the first round. Another round can be played with some industries benefitting from improved cleanup technology. This can be specifically allocated to a few companies as a reduction in pollution control costs. The trading will result in a lower price for pollution rights than previously achieved. Finally, increases in demand for the output of some of the firms may lead to increased production, and derived increases in demand for pollution rights if the regulatory limit is not increased. This will cause the price of emission permits to rise.

A more complicated extension is to provide the firms with more realistic marginal cleanup costs. This would necessitate creating rising marginal abatement cost curves. A straightforward way to do so is make marginal cost a linear function of output for each industry. This change would lead students closer to a marginal analysis in which they would compare the costs of cleanup to the alternatives for each ton of emissions. It would require a more prolonged trading period and may become confusing as trades will occur at different prices as firms move up their marginal cost of abatement curves. This can certainly be done with a smaller group of firms more easily than with a larger group.

This point leads to the final extension of the game, namely adding firms or industries. I have provided examples for three plants only. The game can be expanded easily for a larger class size (or full participation of students) by adding more coal power plants, each with a different cleanup cost. Doing a simple analysis of the demand and supply of emission permits under various allocations will reveal to you what the equilibrium permit price will be.

V. DISCUSSION OF GAME RESULTS

There are many aspects of this exercise that lend themselves to productive classroom discussion. The most important of these is the idea that market-based incentives are a more efficient way to achieve pollution cleanup than command-and-control methods. Thus, students are asked to complete the discussion questions (Appendix II) in order to highlight this result. They will find that pollution cleanup lowers profits across the board (as the companies were all assumed to be profit-maximizers prior to the regulation), but less so than if they all were forced to use cleanup technology to meet emissions goals. They should also find that the companies reduced emissions by different proportions, even though the regulatory mandate initially imposed equi-proportional reductions on each of them. Discussing this result will again emphasize that it is more efficient for society to have cleanup performed in the lowest-cost manner.

This can lead into a discussion about some of the equity issues raised by market-based emissions permits. These include the initial allocation of permits, the issue of a "right to pollute," and ability-to-pay considerations. Students can be asked to argue for different allocation schemes and explore the welfare consequences of granting more pollution rights to bigger polluters (enshrining the status quo and providing windfall benefits to existing firms) versus treating all firms or plants within an industry equally (potentially leading to major transitional costs or shutting down large polluters). The issue of a "right to pollute" can be quite contentious and, if the class is concerned about this aspect or the instructor wishes to explore the ethical questions, a good discussion can arise.

Class discussion should emphasize that achieving pollution reduction more efficiently is not antithetical to, and is more likely to achieve, greater pollution reduction goals. One additional extension of the game is the creation of an environmental organization that is allowed to purchase emission permits with funds raised from membership fees. The class can demonstrate its "willingness to pay" for environmental protection in that manner. Each student can be asked how much they would contribute to an environmental organization dedicated to air pollution reduction and a group can be formed to represent these environmental interests. This group can join in the emission trading market in the subsequent round of trading. It can be instructive to see whether students respond with different willingness to pay for the environmental activity when they realize their companies will face higher abatement costs as permits become more scarce.

Finally, the ability to pay of firms in the emission permit market can be explored, particularly in the case where some firms reduce output (and profits) substantially in complying with the regulatory requirement. A discussion of the relative costs and benefits of this outcome can again be instructive.

VI. TEST QUESTIONS

Below are several examples of test questions relating to the emissions trading game.

1. Graphically demonstrate the welfare results of choosing an emissions trading program to limit pollution as an alternative to command-and-control limitations. Be sure to show the effect on consumers, producers, and social welfare.

2. List the events that would a) lower the price of an emission permit, and b) raise the price of an emission permit.

3. Suppose you are the Environment Czar. Design a program to reduce an air pollutant from current levels in a specific region. Design a program to reduce the pollutant nationwide. What are the problems that may occur a) in implementing the regional program? b) in implementing the national program?

APPENDIX I

Tables for Emissions Trading Game (with Solutions)

TABLE I

Output, Emissions and Profits of Coal Power Plants

	Coal Plant #1	**Coal Plant #2**	**Coal Plant #3**
Current Output	100 bushels	100 bushels	100 bushels
Current Emissions ($E = f(Q)$)	2 tons/bushel	2 tons/bushel	2 tons/bushel
Total Emissions (tons)	*200 tons*	*200 tons*	*200 tons*
Profits ($\pi = f(Q)$)	\$100/bushel	\$100/bushel	\$100/bushel
Total Profits (\$)	*\$10,000*	*\$10,000*	*\$10,000*

APPENDIX I continued

Tables for Emissions Trading Game (with Solutions)

TABLE II

Costs of Clean-up Options for Coal-Fired Power Plants

	Coal Plant #1	**Coal Plant #2**	**Coal Plant #3**
Permits Allocated	100 tons	100 tons	100 tons
Emissions Reduction Required	*100 tons*	*100 tons*	*100 tons*
Cost of Cleanup (per ton of emissions)	$10/ton	$20/ton	$60/ton
Cost to Cleanup to Required Level of Emissions	*$1000*	*$2000*	*$6000*
Opportunity Cost of Reducing Output to Permitted Emissions Level	*$5000*	*$5000*	*$5000*
Permits Traded	*Sell 100 @ $20 each*	*No trade*	*Buy 100 @ $20 each*
Best Choice and Effect on Profits	*Clean 200 tons @ cost of $2000 and sell 100 permits for $20-$50 each. Gain up to $3000 in profits.*	*Clean 100 tons at $2000 and retain 100 tons of permits = lower profit by $2000.*	*Clean no emissions, retain 100 tons of permits, and buy 100 tons of permits @ cost of $20-$50 each. Lower profit by $2000-$5000.*

Tables for Emissions Trading Game (Actual)

TABLE I

Output, Emissions and Profits of Coal Power Plants

	Coal Plant #1	**Coal Plant #2**	**Coal Plant #3**
Current Output	100 bushels	100 bushels	100 bushels
Current Emissions ($E = f(Q)$)	2 tons/bushel	2 tons/bushel	2 tons/bushel
Total Emissions (tons)			
Profits ($\pi = f(Q)$)	$100/bushel	$100/bushel	$100/bushel
Total Profits ($)			

TABLE II

Costs of Clean-up Options for Coal-Fired Power Plants

	Coal Plant #1	**Coal Plant #2**	**Coal Plant #3**
Permits Allocated	100 tons	100 tons	100 tons
Emissions Reduction Required			
Cost of Cleanup (per ton of emissions)	$10/ton	$20/ton	$60/ton
Cost to Cleanup to Required Level of Emissions			
Opportunity Cost of Reducing Output to Permitted Emissions Level			
Permits Traded			
Best Choice and Effect on Profits			

APPENDIX II

Discussion Questions for Emissions Trading Game

Part A. Record of Transactions

1. Which company do you represent? ______________________________
2. How many permits did you keep? ______________________________
3. How many permits did you sell? ______________________________
4. If you sold permits, what price(s) did you receive for your permits? ______________________________
5. What was the total amount your company received for selling permits? ______________________________
6. If your company bought permits, what price(s) did you pay per permit? ______________________________
7. What was the total amount your company spent on permits? ______________________________
8. Did your company install pollution cleanup technology? ______________________________
9. If so, how much did you spend on cleanup? ______________________________

Part B. Discussion Questions

1. What was your company's total annual profits after compliance with the pollution regulations? (Hint: Current profits minus cleanup expenses plus revenues from permit sales minus payments to obtain permits.)
2. How much did this process increase or decrease your company's profits?
3. How much did your company save compared to a scenario where the only choice was to install pollution cleanup technology? (Hint: cleanup costs minus "best choice" cost.)
4. Was your company able to meet its pollution abatement requirement?
5. What percentage of your emissions were eliminated?
6. How would the environmental regulator enforce compliance with these standards?
7. How well do you think the process of permit trading would work in the real world?
8. What are some possible problems with the approach?
9. Does this approach provide incentive for companies to reduce their emissions more than the minimum required amounts?
10. What would happen in the trading process if the environmental regulator decided to reduce emissions even further?
11. What would happen in the trading process if cleanup technology improved and the cost of cleanup equipment dropped?
12. Compare the permit trading approach to other strategies that could be used to achieve pollution reduction.

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