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Use of a Tradable Pollution Allowance Simulation in Teaching Resource and Environmental Policy

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INTRODUCTION

Use of classroom games and simulations is increasingly being promoted as an innovative teaching strategy with potential to improve student interest in learning. By nature, games and simulations involve active learning and many require problem solving and foster critical thinking. Students discover lessons or simulations have been developed to illustrate the economic dimensions of (a) natural resource management (for example, those designed to provide insight into the implication of open-access property rights in managing fisheries, rangeland, or other renewable resources) and (b) environmental policy options (for example, those designed to demonstrate the advantage of pollution allowance trading systems versus traditional pollution control approaches). The relevance of these types of issues to students in fields such as forestry, fisheries, or environmental sciences is obvious. However, natural resource management and environmental policy issues are becoming increasingly important to students in all areas of agriculture. It is quite possible that farmers may one day be able to sell pollution credits, based on actions taken to reduce pollutant loading to waterways or to sequester greater amounts of carbon in their soil. Thus, use of games or simulations on these types of issues offers the potential for important subject matter lessons as well as more general gains in problem solving and critical thinking abilities.

Games and simulations represent one type of learner-centered approach in contrast to the conventional lecture format that treats students as passive receivers of information. Standard lectures may not adequately motivate students to develop a more sophisticated and deeper understanding of the material. Calls for learner-centered instruction are based on a straight-forward premise – students should be responsible for more of the learning process (McCombs and Whistler 1997). Rather than reciting what they have been told, students are more involved in an active process of inquiry and discovery (McKeachie 1994). Motivation to learn is heightened when students are able to exercise some discretion over their own course of action (Paris and Turner 1994).

Student motivation in the context of games and simulations also hinges on a critical balance. The tasks and rules of a classroom game should be challenging but not impossible. If outcomes of the simulation are obvious and the tasks too simple, student interest will quickly fade. Conversely, if tasks are unreasonably complex and the outcome is obscurely related to the subject material, students may refuse to make a significant investment in time and attention to participate. Games and simulations should motivate, not intimidate. If students are to apply their problem solving abilities to the game, the game should be sufficiently complex to motivate students to uncover underlying concepts and principles. Myers (1986) argues that, to foster critical thinking by exposing students to disequilibrium situations, instructors must maintain a proper balance between challenge and support.

Learning in classroom games and simulations can be enhanced by providing opportunities for student interaction. Paris and Turner (1994) argue that social guidance and cooperation in classrooms have now been recognized as fundamental for motivation. Learning is partly a social process. By exchanging ideas with fellow classmates, students not only develop good communication skills, but are able to "weigh" their ideas against each other. Group discussions also can facilitate a deeper understanding of the material by providing a forum to synthesize different perspectives and different abilities of members of the group. As the simulation proceeds, students can become both instructor and student to other members of the group.

But does activity and motivation necessarily translate into gains in critical thinking? Myers (1986) argues that even logic and problem-solving have serious limitations in fostering critical thinking. He goes on to emphasize the importance of other ingredients of critical thinking: "the abilities to make sense of new experiences and to envision possibilities outside one's own immediate experiences (p. 26)" and "the ability to identify principles or concepts in specific experiences that can be generalized to other experiences (p 27)." Participation in the type of game described in this paper (including the standard debriefing discussion) hopefully contributes to students' development of these abilities to some extent. However, a set of follow-up questions are provided in the final section of the paper, questions which are designed to push students further along the learning curve toward critical thinking. These questions can be used in class for an oral discussion within small groups or outside of class as the basis for a written assignment.

A POLLUTION ALLOWANCE TRADING GAME

This section of the paper describes a pollution allowance trading game designed to be an active, learner-centered, exercise. Tradable pollution allowance systems are drawing increasing policy attention as a way to add flexibility and cost effectiveness to environmental regulation (USEPA 1996; Burtraw 1996; Shabman, Stephenson, and Shobe 2002). A pollution allowance trading system allows different discharge sources to exchange pollution control responsibilities. This exchange of allowances at a price determined in the allowance market will result in a voluntary shift of pollution control responsibilities from high control cost sources to low control costs sources, thus lowering the joint costs of control.

While the policy relevance draws most students' attention, the economic logic and processes behind pollution allowance trading systems are not readily apparent to many students. The specific educational objectives of the game and the follow-up discussions are three fold: 1) to demonstrate how a tradable pollution allowance system taps self-interest motivations to lower the cost of achieving an environmental goal, 2) to provide students with practical use of marginal principles, and 3) to demonstrate the equi-marginal principle.

Setting Up the Classroom Game

This game has been developed and conducted in a junior level environmental economics course. The game is played during the first third of the semester when students are introduced to alternative policy instruments that can be used to achieve a given environmental goal. Prior to conducting the game, conventional technology-based performance standard approaches ("command-and-control") have been described and discussed in a lecture. Tradable allowance systems are then briefly identified as an alternative, but the primary purpose of the classroom experiment is to provide a substitute for the introductory lecture.

The game is designed for a class of 16 to 32 students and can be conducted in one class period. The class is divided into eight private "firms" and the students are informed that they are responsible for jointly managing their firm. Students are told that through their firm's production practices, each firm is currently discharging 200 tons of nitrogen into the same body of water. Part of their job responsibilities involves managing their firm's effluent discharge. The instructor plays the role of the regulatory agency assigned to protect ambient water quality.

Students are then given a nitrogen abatement marginal cost schedule (see Figure 1). The marginal cost schedules are different for each firm and discharges can be reduced in 20 pound increments (see Appendix). The students are not told their competitors' cost schedules.

Working with the other "managers" of their firm, the students are asked to calculate total nitrogen control costs for each level of nitrogen discharge. The students work cooperatively to calculate total nitrogen control costs while the instructor's role is limited to checking the final calculations for each firm. The class is then informed that current collective discharge levels of 1,600 tons of nitrogen (200 tons for each of the eight firms) is adversely impacting local water quality. The instructor informs the eight firms that the state legislature has decided that a forty percent reduction in total nitrogen discharges is needed to restore water quality to a level compatible with recreational uses. To add to the relevance of the game, the forty percent reduction goal is also the actual nitrogen reduction target established for the Chesapeake Bay. The regulator's duty is to design a policy to reduce aggregate nitrogen discharges to 960 tons.

Running the Game

Students are told that the regulator has decided to create a tradable nitrogen allowance system to achieve the legislated environmental goal. Each allowance permits the firm to discharge one ton of nitrogen into the receiving water body within a fixed time frame, such as one year. Each firm is then granted 120 allowances, a 40 percent reduction for each firm. The instructor may wish to point out to the class that if all firms are required to reduce discharges to 120 pounds, then the environmental goal will be achieved through a performance standard.

The class is then informed that future regulatory duties will require the managers to specialize. The managers of the firms will be required to perform two duties, accounting and negotiation. The students of each firm then select one person to perform the accounting duties. The remaining “managers” of the firm are negotiators. The accountants of each firm are handed a pollution accounting balance sheet (see Figure 2). The balance sheet is briefly explained and the accountants are asked to record the total number of allowances each firm now holds (120) and the total cost of reducing nitrogen discharge to this level.

At this point the “regulator” announces that a tradable nitrogen allowance system is going to be created. The instructor explains that a firm can either buy allowances from one of the other seven firms or can sell some of their current allowance holdings (120 allowances). The instructor asks each firm two questions sequentially -- “What is the maximum price your firm would be willing to pay for 20 allowances?” and “What is the minimum price your firm would be willing to accept to sell 20 allowances?” Students are reminded to discuss each question only with members of their firm. This is the most time consuming portion of the experiment and some students have some initial difficulty fully understanding the answers to these two questions. At this point the role of the instructor is to individually confirm that each firm has come up with its correct answer or prod group members with additional questions until at least one individual in each firm understands the concept. Inevitably, some students grasp the concept quicker than others and this presents an excellent opportunity for student guided instruction.

The "market" for allowances is then opened. Each firm sends a negotiator to the front of the room where eight chairs are arranged in a circle. Students are then permitted to exchange allowances. As students begin negotiating, some students may become confused about what bid and sell price to offer. At this point, students are not yet aware whether their firm will be a buyer or seller of allowances. Consequently, during the initial round, it is often helpful for another student to accompany the appointed negotiator to the “market” to act as an advisor.

In most cases, the exchange of allowances generates a great deal of excitement among the students. As negotiators search for acceptable deals, they often receive ample advice from other members of their firm. Often the exchange of allowances resembles a cross between trading on the commodities exchange and the game show the “Price is Right.”

After negotiators finalize a trade, they return to their respective firms with the sale price information. Given the buy or sale price, the accountant then records and calculates the new discharge level of the firm and the new total allowance holdings. Net pollution control costs are calculated as total nitrogen control expenditures less revenue from the sale of allowances plus expenditures of new allowances. Many students are surprised to learn that they could spend money to purchase allowances and still reduce the overall net pollution control costs.

Given the cost structures of the eight firms, three separate rounds of trading will occur. For simplicity, firms are only allowed to exchange 20 allowances in each round (one transaction per round). In each round the firms are told they must utilize a different negotiator, thus ensuring some minimal level of participation from each student in the class. Given the cost structures of these particular firms, there will be four buyers and four sellers among the eight firms. Thus, each firm should be able to trade allowances with another firm during the first two rounds. During the third round, only one trade is possible. The third round is intended to remind the students that trading cannot continue indefinitely and that an equilibrium will be established after the third round of trading.

During most of the class, the instructor's goal is to intervene as little as possible. The aim is to ensure that the bid and sell price information is correctly understood and recorded into the accounting balance sheet. The students are responsible for conducting the lesson.

Post-Game Classes

The classroom game forms the basis for subsequent discussions on pollution allowance trading. During the course of the game, each student has witnessed the net pollution control costs of their firm decrease. Some students seem to sense that trading is a zero sum game and that their good fortune is coming at the expense of other firms. In subsequent class periods it is important to take firm level perceptions and successfully connect them to a broader understanding of the overall functioning of a trading system. Furthermore, follow-up classes can be conducted outside the traditional lecture format by having the students piece together the big picture from their individual experiences.

At the end of the game, the instructor collects the pollution accounting balance sheets from the accountants. In the next class period, the instructor provides each student a copy of his/her firm's balance sheet. The information from each firm will be collected during the course of the class period and will be used to construct four tables. The rows of each table are labeled with the name of each of the eight firms with a summary row at the bottom of the table. The column headings will include the two alternative pollution control strategies being investigated -- performance standard ("command-and-control") and tradable allowances. The students use the information created in the previous day's game to construct a lecture.

The four tables summarize the different aspects of a tradable pollution allowance system and compare the results to a performance standard (command-and-control approach). The four tables are: 1) "Total Nitrogen Discharge", 2) "Net Pollution Control Costs", 3) "Nitrogen Control Costs", and 4) "Marginal Cost of Pollution Control." Starting with the "Total Nitrogen Discharge" table, the instructor will ask each firm to report its total nitrogen discharge before and after trading. The answers are recorded on the table displayed on either the chalkboard or overhead. The results of the performance standard and tradable allowances columns will be summed and shown to be equal.

The "Net Pollution Control Costs", "Nitrogen Control Costs", and "Marginal Cost of

Control" tables are then constructed in succession. The "Net Pollution Control Costs" table is intended to show the class that all eight firms reduced their total pollution compliance costs (allowance trades and nitrogen control expenditures). The "Nitrogen Control Costs" table shows that while the total expenditures on nitrogen control went up, the total amount of societal resources devoted to pollution control decreased through trading. The results are often surprising to the students. More importantly, the students have their own behavioral responses and experience from the game to anchor with the economic concepts being revealed. The "Marginal Cost of Control" table provides a hands-on demonstration of the equi-marginal principle: equalization of marginal costs between firms lowers the total cost of achieving a given environmental goal. After trading, students are shown that the marginal cost of control for their firms are now roughly equal to the other seven firms. It is stressed that the very existence of differences in marginal costs makes gains from trade possible.

The game emphasizes the economic advantages of grading given existing technologies. However, the game does not reflect an important economic feature present in most trading systems – the incentive for cost reduction through new technologies. In actual applications of trading systems, significant cost savings can be achieved without trading. The establishment of a trading system offers firms an incentive to reduce costs (the price of an allowance) and provides firms decision-making flexibility to respond to this price signal. A tradable pollution allowance system fosters and encourages the development of new, low cost ways to control pollution. In essence, the trading system creates incentives for firms to reduce their marginal cost of control schedules (Stephenson and Shabman 1996). Follow-up class discussions should point out this important dynamic aspect of a tradable pollution allowance system

Modifications and Extensions

There are a number of possible modifications that could be made to the simulation, with a view toward increasing realism and helping students understand practical challenges actually implementing in trading programs. One logical extension, based on the final paragraph in the previous section, would be to incorporate an option for investments in research and development that may produce new cost-reducing technologies. Another simple extension would be to introduce other groups into the trading system by permitting an environmental group to purchase allowances. For example, in the national SO_2 allowance trading program, trading is open to anyone. The game could also be modified to focus on design issues of a trading system. A negotiating framework between the regulator, environmental groups, and the firms could be created to address monitoring issues and potential effluent distribution problems. The basis for the initial assignment of allowances could be changed, allowing exploration of the economic and political implications.

Follow-up questions

As was mentioned at the end of the introductory section, questions such as those listed below can be used for oral discussion or written assignments. These questions are designed to challenge students to think critically, through the process of exploring issues related to the real-world application of policies based on the economic principles demonstrated in this simple game.

QUESTION 1

Economists have suggested that conceptually, a pollution tax of a certain amount per unit of pollutant discharged would lead to exactly the same outcome as a pollution allowance trading system, with respect to the overall reduction in pollution discharges and the overall cost of pollution control efforts to achieve that reduction. Which approach do you think would be preferred by the following stakeholder groups, and why?

- Environmentalists, who highly value pollution reductions
- Businesses, who face pollution discharge regulations
- Bureaucrats, who must enforce pollution control policy

QUESTION 2

In some watersheds, point source pollution dischargers are already strictly regulated and face relatively high marginal costs for further nutrient discharge reductions. Yet, water quality problems still exist. Relatively low marginal cost options exist for reducing nutrient discharges from agricultural nonpoint sources (e.g., cropping, tillage, and nutrient management practices). What factors must be considered in design and implementation of a point-nonpoint trading system, wherein point dischargers could avoid having to achieve further discharge reductions by purchasing credits generated by actions on the part of agricultural nonpoint sources? What equity issues between point and nonpoint sources are involved in point/nonpoint trading schemes?

QUESTION 3

Based largely on the success of the Acid Rain Allowance trading (ARAT) Program for sulfur dioxide emissions from coal-fired electrical utility plants in the U.S., most policy analysts recommend an international trading system for reducing greenhouse gas emissions (GGE's) to counter the treat of global warming. Countries would be assigned caps for their GGEs which could only be exceeded if excess allowances were purchased from other countries. Identify the important ways in which this situation differs from the situation to which the ARAT Program was applied. Discuss the implications of these differences for the potential cost savings from a trading system for GGEs and the challenges/complications of designing and implementing such a system.

QUESTION 4

The general logic of a pollution allowance trading system can conceivably be applied to a variety of resource management and environmental quality goals. Brainstorm to identify two or three of such goals with respect to agriculture production, forestry practices, or fisheries management. Discuss how these goals might be characterized or defined in a way that would allow a "cap-and-trade" type of approach to be implemented as a way to minimize the social costs of achieving these goals. Attempt to identify any major drawbacks or limitations to applying such an approach in these cases.

Figure 1. Nitrogen Abatement Marginal Cost Schedule

Firm 1

		CONTROL COSTS	
Tons of Nitrogen Discharged	**Tons Reduced**	**Marginal Cost**	***Total Nitrogen Control Costs***
200			________
180	20	$50 (per ton)	________
160	20	$100	________
140	20	$150	________
120	20	$200	________
100	20	$250	________
80	20	$350	________
60	20	$450	________
40	20	$800	________

Figure 2. Pollution Accounting Balance Sheet

Firm_____

1 Number of N Allowances Held	**2** Total N Control Costs	**3** Number of Allowances Bought	**4** Price Per Allowance	**5** Total Cost of Allowances	**6** Number of Allowances Sold	**7** Price Per Allowance	**8** Total Revenue from Sale of Allowances	**9** **Net Pollution Control Costs***

*Net pollution costs are total nitrogen control costs plus/minus what was spent or received from allowance transfer
NET POLLUTION CONTROL COSTS = (Total Nitrogen Control Cost) + (sum of column 5) - (sum of column 8)

Firm Managers:____

Appendix

Firm 1

Tons of Nitrogen Discharged	Marginal Cost
200	
180	$50 (per ton)
160	$100
140	$150
120	$200
100	$250
80	$350
60	$450
40	$800

Firm 2

Tons of Nitrogen Discharged	Marginal Cost
200	
180	$300 (per ton)
160	$650
140	$900
120	$1,300
100	$2,000
80	$2,500
60	$3,000
40	$4,000

Firm 3

Tons of Nitrogen Discharged	Marginal Cost
200	
180	$25 (per ton)
160	$50
140	$100
120	$150
100	$200
80	$300
60	$475
40	$850

Firm 4

Tons of Nitrogen Discharged	Marginal Cost
200	
180	$150 (per ton)
160	$300
140	$500
120	$750
100	$1,100
80	$1,500
60	$2,000
40	$3,500

Firm 5

Tons of Nitrogen Discharged	Marginal Cost
200	
180	$150 (per ton)
160	$300
140	$450
120	$700
100	$1,000
80	$1,500
60	$2,000
40	$2,500

Firm 6

Tons of Nitrogen Discharged	Marginal Cost
200	
180	$50 (per ton)
160	$100
140	$150
120	$200
100	$250
80	$375
60	$600
40	$1,500

Firm 7

Tons of Nitrogen Discharged	Marginal Cost
200	
180	$25 (per ton)
160	$50
140	$100
120	$150
100	$225
80	$350
60	$800
40	$1,500

Firm 8

Tons of Nitrogen Discharged	Marginal Cost
200	
180	$200 (per ton)
160	$400
140	$650
120	$900
100	$1,200
80	$1,500
60	$2,000
40	$3,000

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