Choosing Winners and Losers in a Permit Trading Game

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Abstract

This paper presents a classroom game in which students trade pollution permits. By changing the distribution of permits across firms, the game shows students how the allocation of property rights determines the winners and losers in the permit trading system, but does not affect the efficiency of the system. This game can be used in a variety of classes including principles or environmental economics and can be conducted in a 50 minute class period with follow-up discussion in the next class.

Introduction

In many economics classes from principles to environmental economics and public finance, we teach students that tradable pollution permits are an efficient way to achieve a socially optimal level of pollution. This can be shown to students relatively easily using standard firm cost curves or simply by discussing how firms that can cheaply reduce their pollution can sell their rights to firms with higher pollution reduction costs.[1] It is often more difficult to convince students that, for a fixed level of permits, the initial allocation of permits does not affect the efficiency of the trading program, but only the distribution of the financial burden of reducing pollution.[2] Understanding the distributional effects of trading programs is important because equity issues are what make some trading programs controversial. For example, the initial allocation of permits is one of the contentious issues in developing an international tradable permit program for greenhouse gas emissions.

To illustrate the distributional effects of a permit-trading program, we have developed a simple classroom game. This game can also be used more generally to show how the distribution of property rights determines who internalizes an externality but does not affect whether the social optimum is achieved. This game can be conducted in a 50-minute class with a short follow-up discussion in the next class period and requires only a deck of playing cards, index cards, and copies of the instructions and record sheets in the appendix.

Setting up the Permit Trading Market

This game is designed for nine "firms" but can easily be expanded to accommodate more firms. Firms may consist of one or more students, but we recommend no more than four students per firm to ensure that each student is involved in the decision making process.[3] Additionally, you will need two students to help run the game. Each firm can produce up to two units of a

[1] Nugent (1997) presents a game that demonstrates the efficiency benefits of a permit trading program as opposed to command and control regulation.

[2] Of course, the total number of permits does affect the efficiency of the trading program.

[3] The easiest way to expand the game is to replicate the game, that is have a total of 9X firms (X of each type). For example, we ran the game in a class of 75 students using 27 firms with 2 to 3 students per firm.

good that can be sold in a competitive market at a price of $12. The good costs nothing to produce, but production results in one unit of pollution per unit produced.[4]

Distribute the instructions and record sheets to the students so they can keep up with transactions and earnings.[5] Each student should have a copy of the instructions, but you only need to distribute one record sheet per firm. Give each firm a number or name and have the students write the firm's identity on the record sheet. Read through Part I of the instructions. In the first period, there are no restrictions on pollution. Have each firm decide how much to produce. Since production is costless and the good can be sold for $12, each firm should produce two units of the good, and therefore two units of pollution.

In the second period, you announce that Congress is concerned with the level of pollution from this industry and therefore the Environmental Protection Agency has decided to regulate the level of pollution each firm emits (Part II from the instructions). Give each firm an index card, which represents a permit for one unit of pollution. Explain to the firms that they must have a permit for every ton of pollution that they emit. If the firm generates more pollution than they have permits, they must clean up the pollution. However, cleaning up pollution, also known as pollution abatement, is not costless. Each firm will have a different abatement cost depending on the technology that firm employs and the age of their plant. To represent the cost of abatement, use the playing cards from two through ten, and give each firm one card. The cost of cleaning up one unit of pollution is the number on the playing card that they are given. In this period, do not let firms trade permits. The assistants can check record sheets to verify that firms abate one unit of pollution if they choose to produce two units of the good, since they have only one pollution permit to relinquish. Collect all pollution permits at the end of the period.

In period three, redistribute the permits, one to each firm, and announce that they may trade permits among themselves (Part III instructions). Explain that the trading will take place in a pit market setting.[6] Designate an area of the room for trades to take place. Each firm that wants to buy a permit should send a representative to the pit market to announce, loudly, the price at which they will buy, and each firm that wants to sell a permit should send a representative to the pit market to announce the price at which they are willing to sell. Once a buyer and seller agree to trade, have them report it to you or to one of the assistants. Record the price at which the permit was traded as well as the identities of the buyer and seller. This allows you to track the abatement costs of the buyers and sellers. Announce the prices at which permits are trading or write the prices up on the board so that other traders know what the prevailing prices are. Set a five-minute limit for the permit-trading portion of the period. At the end of the trading period, remind students to record transactions on their record sheets. You and the assistants should again verify that firms incur the abatement cost for pollution that is not exempted with a permit. At the end of the period, collect all of the permits and redistribute so that each firm again has one permit. Conduct two or three rounds of trading with this equal distribution of permits. Do not redistribute cost cards. Firms should have the same abatement

[4] If students inquire why price is greater than cost in this competitive market, remind them that accounting costs and opportunity costs are not the same. While the good costs nothing to produce, the firms involved in the market are forgoing other opportunities.

[5] In our experience financial rewards are not necessary to motivate students in classroom games, but to increase interest, you can offer to pay a randomly selected firm a small percentage of earnings.

[6] Holt (1996) provides a comprehensive guide to pit market trading in a classroom.

cost for the entire experiment to emphasize the effect of different permit distribution schemes on earnings.

Once the price of a permit has converged to the equilibrium prediction under a uniform distribution, collect all of the permits and redistribute them. For the remaining periods you should use alternative methods to distribute permits. If you wish, you may draw numbers to ensure that the redistribution is random. For example, you can throw a 10-sided die nine times to determine which firm (1 - 9) gets each permit.[7] Using this allocation method, it is likely that some firms will get more than one permit and some firms will get no permits. You may also want to strategically redistribute the permits. For example, give all of the permits to the low cost firms in one period and to the high cost firms in the next period. For each period in which the permits are not distributed uniformly, keep track of the number of permits each firm is given.

Class Discussion

You may want to begin the class discussion by noting that the imposition of regulations on pollution lowered firm profits. Ask students if they think this means that environmental regulation is harmful. The students should be reminded that pollution causes a negative externality because it imposes costs on society. Therefore, regulations designed to remedy the externality are designed to internalize the externality, that is make the firm be accountable for the external costs they impose. However, the costs that regulation imposes on firms are not necessarily equal to the externality.

Next, talk about firm profits after firms were allowed to trade permits. Most firms should have made a higher profit when they were allowed to trade and permits were distributed uniformly than when they were not allowed to trade. Ask someone who bought a permit to explain why. Specifically, ask him how much he paid, and how much he would have been willing to pay. You should also ask a student who sold a permit to explain why he sold his permit and how much he got for it. Discuss why the sellers of permits were those with relatively low abatement costs and the buyers were those with relatively high abatement costs. You can create a version of table 1 with results from the experiment on the blackboard. The columns labeled "Abatement Costs of Buyers" and "Abatement Costs of Sellers" highlight the fact that permits are generally traded from firms with low abatement costs to firms with high abatement costs.

Remind the students that in the permit market they acted as both consumers and suppliers. Each firm is a potential consumer because each firm creates pollution. Each firm that has a permit is a potential supplier. The demand for permits is based on the firms' willingness to pay for permits and should be based on the price of permits relative to the cost of the alternative, abatement. Have students consider their willingness to pay for permits assuming that they have not been given any permits by the EPA.[8] Start at $10 and ask each firm that would have bought a permit at that price to have a representative raise her hand. Firms with abatement costs of $10 are indifferent about buying at this price, so you may have students raise their hands or you may not. Next ask how many would have bought a permit at $9. Count the number of hands and use

[7] If the die throw results in a 10, roll again for that permit.
[8] Willingness to pay for permits should be thought of independently of the allocation of permits.

this to begin drawing a demand curve on the board. The number demanded will be equal to the number of firms times 2, since each firm can produce two units of the good. Then ask who would have bought a permit at $8, $7, etc. Use this information to draw the demand curve in Figure 1.[9] Explain that you have derived this demand curve from the firms' willingness to pay for a permit and that it is independent of the allocation of permits. Note that each polluter would be willing to pay for a permit as long as the price of that permit is below their cost of abatement. Hence, the demand curve is the same as the marginal abatement cost curve.

Next discuss supply. Remind the students that firms base supply decisions on marginal cost. In this game, the marginal cost of a permit is zero. Ask students what they think the supply curve should look like. If the students propose a curve that is not a vertical line at the number of permits, it is because they are not thinking of supply and demand separately. Pick a student and ask him if he would have sold his permit for $1. If he answers no, ask him why not. He will probably say that at that price he would use the permit himself. Explain that the firm is acting as both a buyer and a supplier. If the firm chooses to use one of the permits it has been given rather than selling it, in effect the firm has "sold" that permit to itself. Because a permit is costless for the firm, every permit should be either used by the firm (sold to itself) or sold to another firm. Therefore, supply is fixed at the number of permits.[10]

The intersection of the supply and demand curve will determine what the equilibrium price for permits will be. You should discuss why prices other than the equilibrium price do not clear the market. For example at a price of $4, all firms with abatement costs greater than $4 (six firms) will want to buy permits but only those firms with abatement costs less than $4 (two firms) will want to sell permits, so there will be excess demand. At a price of $8 only firms with abatement costs greater than $8 (two firms) will want to buy permits and all firms with abatement costs less than $8 (six firms) will want to buy, so there will be excess supply. Only at $6 is the number of firms willing to sell (four firms) equal to the number of firms willing to buy (four firms).

Note that the intersection also tells us how many permits are used in equilibrium, all the permits, but does not tell us how many are traded because the number that are traded depends on which firms are given the permits. Who is given a permit is important because that affects whether the firm will use the permit itself or trade it to another firm that has a higher value (willingness to pay) for the permit.

Discuss whether the equilibrium price of permits will change when permits are allocated randomly. Ask the students whether the demand curve or the supply curve shifts when permits are reallocated. If neither demand nor supply shifts, is there any reason to expect that the equilibrium price or quantity should change? All that has changed with the reallocation of the permits is the ownership of the permits. Therefore the price at which permits are traded should be relatively similar across periods regardless of the allocation.

[9] Note that this figure assumes firms would buy a permit if the price equals their abatement costs.

[10] An alternative method to generate supply and demand curves is to have each firm indicate how many permits they were willing to buy and sell given their initial endowment of permits. In this way, the supply curve is upward sloping and the intersection of supply and demand predicts the number of permits traded, rather than the number redeemed. The price prediction is invariant to the method used to derive supply and demand.

You can also compare earnings across periods with different allocation schemes. Average profits should be relatively stable, but individual firms can experience significant increases and decreases. Figure 2 shows the results of the reallocation of permits in a classroom setting. Large differences in earnings may lead to a normative discussion of who should initially be given the permits. You may want to discuss the possible allocation of international greenhouse gas permits. Should the countries with the highest costs of reduction receive the permits? Which countries do the students think will have the highest cost of reduction, developed countries or developing? Should permits be allocated to the countries that are most harmed by greenhouse gas emissions, and if so, which countries suffer the greatest harm?

Extensions and Variations

There are a number of different extensions or variations you can introduce. For example, you can announce that an environmental group that has offered to buy up to X permits at $X each. This increases the demand for permits and should increase the equilibrium price of permits. You can also announce that the EPA determined that the level of pollution in the environment is still too high and decrease the supply of permits. Rather than distribute the permits to firms at no cost, you can auction the permits using an English auction.[11] This should not affect the efficiency of the permit scheme, as the firms with the highest pollution reduction costs should buy the permits. However, this should lower the profits of all firms. Discuss the pros and cons of this situation versus giving the permits away. For example, compare the additional revenues collected by the government to the costs of conducting the auction.

Further Reading

For more information on the economics of permit trading systems, Tietenberg (1985) provides a comprehensive overview while Ross (1998) discusses the feasibility of a permit trading system in the context of an international agreement on greenhouse gas emissions. Experiments on permit trading systems include Plott (1983) which compares a command-and-control system to a permit system in laboratory markets and finds that the permit system is more efficient at extracting surplus from the market. Harrison et al. (1987) also found that efficiency improved with the permit trading system. However, unlike in the Plott setup, trades took place through informal negotiations. This resulted in lower overall efficiencies in the Harrison et al. experiments. For more recent research, the current volume of *Research in Experimental Economics* (1999) is devoted entirely to permit trading papers.

[11] Chapter 5 of Davis and Holt (1993) discusses an English auction and reviews related experimental results.

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Table 1. Results from a Classroom Permit Trading Game with 27 Firms

Period	Treatment	Predicted Number of Trades	Actual Number of Trades	Average Price	Abatement Costs of Buyers	Abatement Costs of Sellers	Average Profit
1	No Regulation	----------	----------	----------	----------	----------	$24.00
2	No Trading	----------	----------	----------	----------	----------	$18.00
3	Uniform Allocation	12	10	$6.30	10,10,9,9, 9,8,8,7,6,2	2,2,3,3,3,4, 4,5,7,7,	$19.48
4	Uniform Allocation	12	10	$6.55	10,10,9,9, 9,8,8,8,7,7	2,2,2,3,3,4, 4,4,5,5	$20.00
5	High/Low	9	9	$6.28	9,9,9,8,8,8, 7,7,3	3,3,3,4,4,4, 5,5,6,	$20.22
6	Random Allocation	13	11	$5.91	10,10,9,9,9 9,8,8,7,6,4	2,2,2,2,2,2, 3,4,5,5,6	$20.11

Note: This experiment was conducted in a Principles of Microeconomics class at the College of William and Mary, Spring 1999.

Treatments: "No Regulation" indicates that there was no restriction on pollution and no permits were issued. "No Trading" indicates that pollution was restricted and permits were issued, but no trading of permits was allowed. "Uniform" indicates that each firm was given one pollution permit and trading was allowed. For "High/Low" the firms with the highest abatement costs were each given 2 permits and the firms with the lowest were given no permits. "Random Allocation" indicates that the permits were distributed randomly (depending on the birthdays of the firm members).

Figure 1. A Market for Pollution Permits

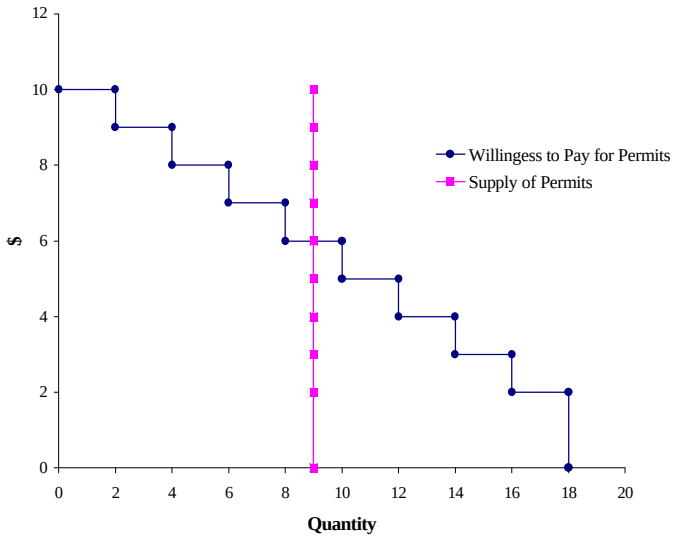
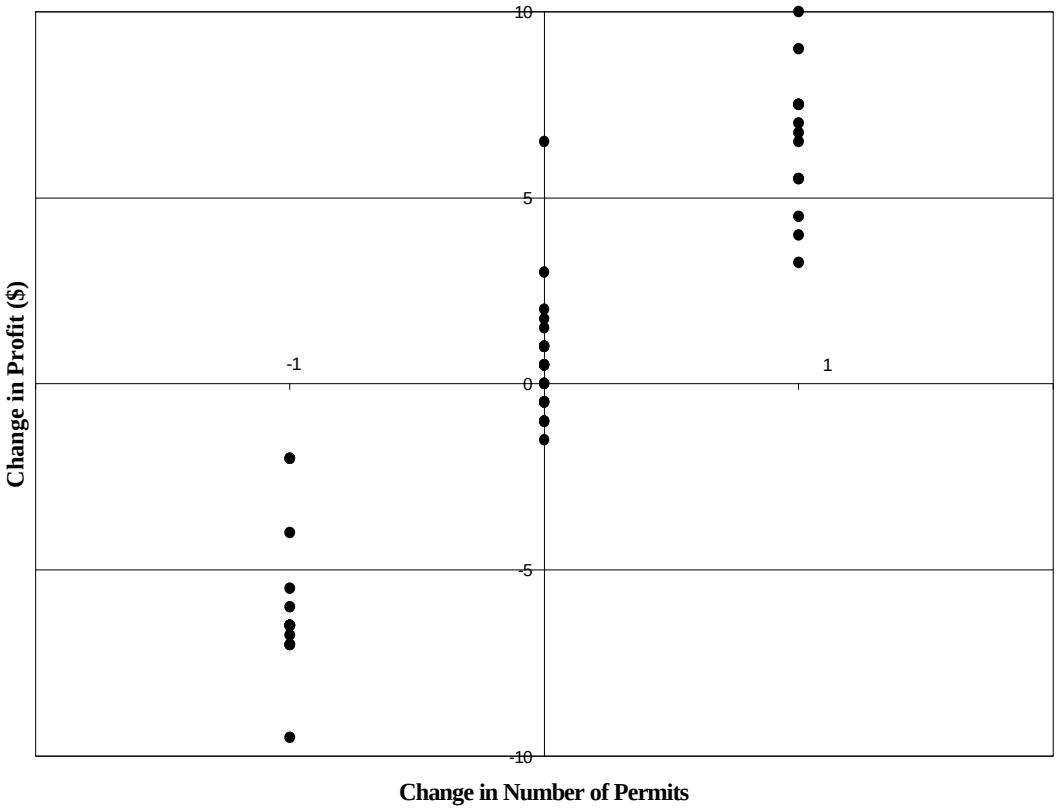


Figure 2. Change in Firm Profit due to Changes in Permit Allocations



Appendix: Instructions

In this experiment, you are all producers of a good that can be sold on the open market for $12 per unit. The good costs nothing to produce, but production results in one unit of pollution per unit produced. There will be a number of decision making periods. In each period, you have the opportunity to produce up to two units of the good. You should keep track of transactions that take place on the attached record sheet.

Part I

In this part of the experiment, you should choose your level of production (0, 1, or 2 units), and record this and your "revenue from production" ($12 * your level) in columns (1) and (2) on your record sheet. Transfer this amount to column (6) labeled "earnings." Disregard columns (3) - (5) since they are irrelevant for this part of the experiment.

Part II

Your production process causes damage to the environment, and hence has been regulated by the Environmental Protection Agency. For each unit of the good that you produce, you must either submit a pollution permit or incur a cost to abate the pollution. The cost of abatement is the number on the card that you have been given and this cost is incurred for each unit of pollution that you abate. At the beginning of period 2, we will give each of you one pollution permit. As in period one, you must decide how many units to produce. If you choose to produce one unit, you will emit one unit of pollution and must relinquish your pollution permit. If you choose to produce two units, you must relinquish your pollution permit and you must pay the cost (on your card) to abate one unit of pollution. All permits held at the end of the period have no value and must be returned. Complete columns (1), (2), (3), and (6) for this period and ignore columns (4) and (5).

Part III

In period 3, you will be regulated in the manner described above. As in period 2, you will each be given one permit and you must pay the abatement cost on your card for any units you produce without permits. At the beginning of this period, you will be given 5 minutes to buy and sell permits from each other. If you wish to buy or sell a permit, you should come to the trading area at the front of the room and announce that you will buy or sell a permit, and the price at which you are willing to make that transaction. You may negotiate with one or more firms if you so desire. At the end of the 5 minutes, you must commit to a level of production (0 units, 1 unit, or 2 units), submit any permits that you have, and pay abatement costs for any units that you produce without accompanying permits. If you hold one permit and produce two units, you incur the cost on your card to comply with the EPA regulation. If you have no permits at the end of the period and you choose to produce two units of the good, you incur two times the cost number on your card to comply with the EPA regulation. Permits cannot be carried over from period to period. Subsequent periods will be conducted in a similar manner, however, the initial distribution of permits may vary from period to period. Complete all six columns on your record sheet for this part of the experiment.

Record Sheet for Firm _____

(0)	(1)	(2)	(3)	(4)	(5)	(6)
Period	Number of Units Produced	Revenue from Production ($12 * units produced)	Cost of Abatement (# on card * units abated)	$ Spent on Permits	$ Earned from Permits	Earnings (2) - (3) - (4) + (5)
1			----------	----------	----------	
2				----------	----------	
3						
4						
5						
6						
7						
8						
9						
10						