FIGURE 17.6 **Plott's laboratory model of a market with an externality.**

Economic theory predicts that the market, if left alone, will ignore the externality and will reach its equilibrium at point *B*, where the private marginal cost curve *MC* and the demand curve intersect. Point *A*, where the social marginal cost curve *MC′* and the demand curve intersect, is the optimal solution for society.

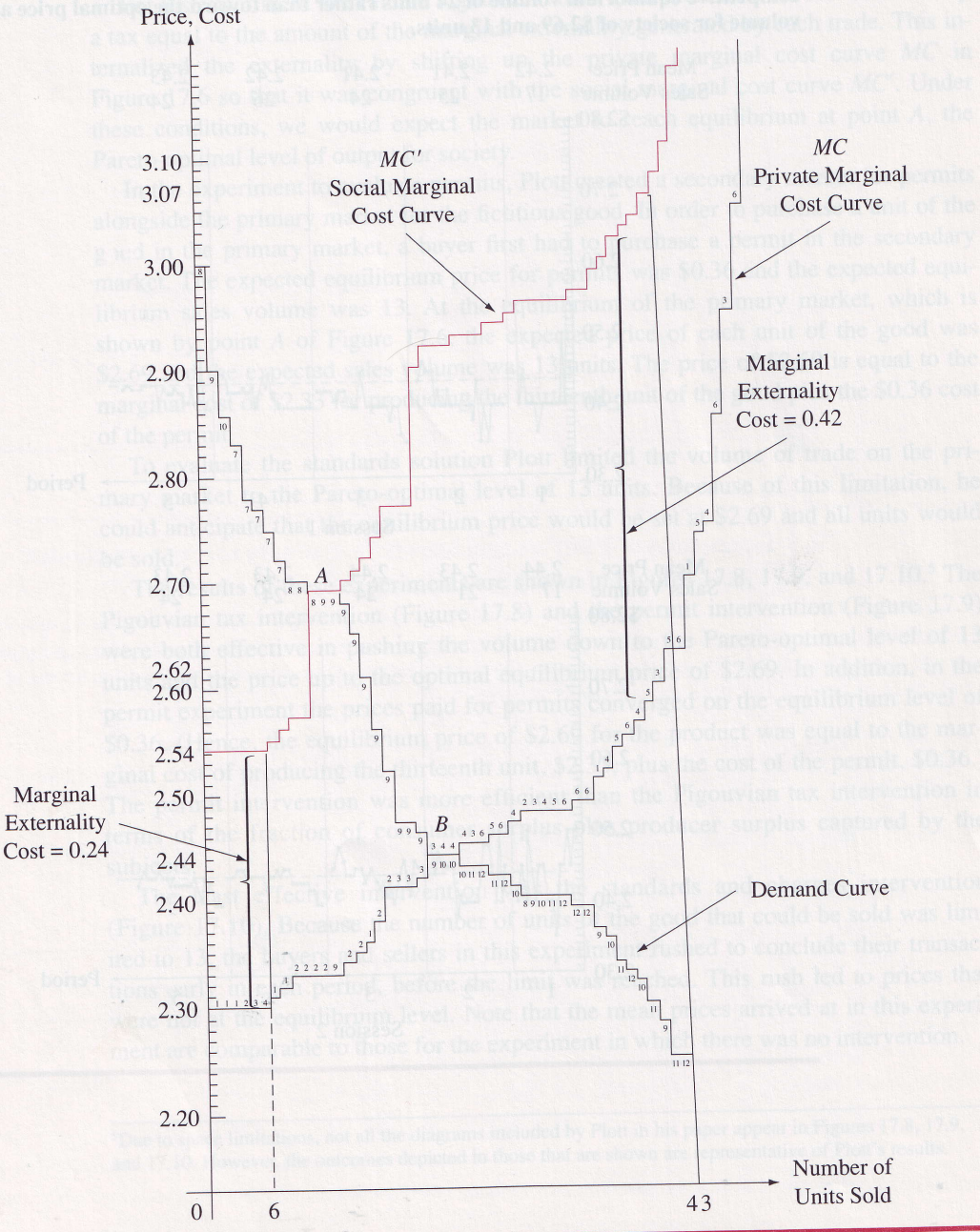
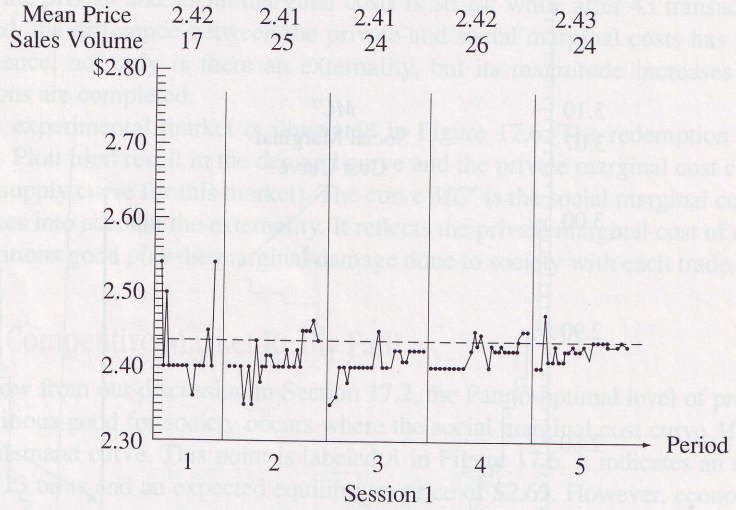
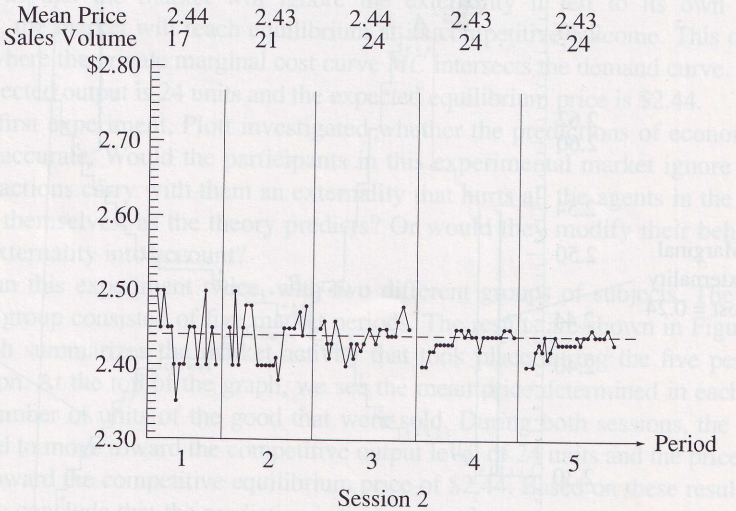


FIGURE 17.7 **The results of Plott's experiment to investigate the behavior of a market with an externality.**

As economic theory predicts, the prices in the experimental market moved toward the competitive equilibrium price of $2.44 and the quantities sold moved toward the competitive equilibrium volume of 24 units rather than toward the optimal price and volume for society of $2.69 and 13 units.





Evaluating the Interventionist Solutions

Having established that his experimental market would fail in the absence of a mechanism requiring the subjects to take the externality into account, Plott then ran additional experiments to evaluate the efficacy of three interventions—Pigouvian taxes, permits, and standards.

For his experiment to evaluate Pigouvian taxes, Plott increased the cost schedule by a tax equal to the amount of the marginal externality generated by each trade. This internalized the externality by shifting up the private marginal cost curve *MC* in Figure 17.6 so that it was congruent with the social marginal cost curve *MC′*. Under these conditions, we would expect the market to reach equilibrium at point *A*, the Pareto-optimal level of output for society.

In the experiment to evaluate permits, Plott created a secondary market for permits alongside the primary market for the fictitious good. In order to purchase a unit of the good in the primary market, a buyer first had to purchase a permit in the secondary market. The expected equilibrium price for permits was \$0.36 and the expected equilibrium sales volume was 13. At the equilibrium of the primary market, which is shown by point *A* of Figure 17.6, the expected price of each unit of the good was \$2.69 and the expected sales volume was 13 units. The price of \$2.69 is equal to the marginal cost of \$2.33 for producing the thirteenth unit of the good plus the \$0.36 cost of the permit.

To evaluate the standards solution Plott limited the volume of trade on the primary market to the Pareto-optimal level of 13 units. Because of this limitation, he could anticipate that the equilibrium price would be set at \$2.69 and all units would be sold.

The results of these experiments are shown in Figures 17.8, 17.9, and 17.10.[5] The Pigouvian tax intervention (Figure 17.8) and the permit intervention (Figure 17.9) were both effective in pushing the volume down to the Pareto-optimal level of 13 units and the price up to the optimal equilibrium price of \$2.69. In addition, in the permit experiment the prices paid for permits converged on the equilibrium level of \$0.36. (Hence, the equilibrium price of \$2.69 for the product was equal to the marginal cost of producing the thirteenth unit, \$2.33, plus the cost of the permit, \$0.36.) The permit intervention was more efficient than the Pigouvian tax intervention in terms of the fraction of consumer surplus plus producer surplus captured by the subjects.

The least effective intervention was the standards and charges intervention (Figure 17.10). Because the number of units of the good that could be sold was limited to 13, the buyers and sellers in this experiment rushed to conclude their transactions early in each period, before the limit was reached. This rush led to prices that were not at the equilibrium level. Note that the mean prices arrived at in this experiment are comparable to those for the experiment in which there was no intervention.

[5]*Due to space limitations, not all the diagrams included by Plott in his paper appear in Figures 17.8, 17.9,* and 17.10. However, the outcomes depicted in those that are shown are representative of Plott's results.

FIGURE 17.8 **The results of Plott's experiments to evaluate the interventionist solutions to an externality: The Pigouvian Tax.**

The Pigouvian tax intervention pushed prices and quantities toward the optimal levels for society of $2.69 and 13 units.

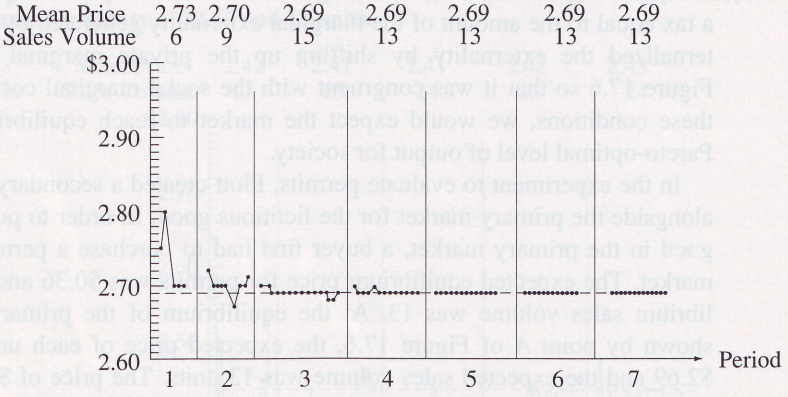


FIGURE 17.9 **The results of Plott's experiments to evaluate the interventionist solutions to an externality: Permits.**

Like the Pigouvian tax intervention, the permit intervention succeeded in pushing prices and quantities toward the optimal levels for society. However, the permit intervention was more efficient in terms of the amount of consumer and producer surplus captured.

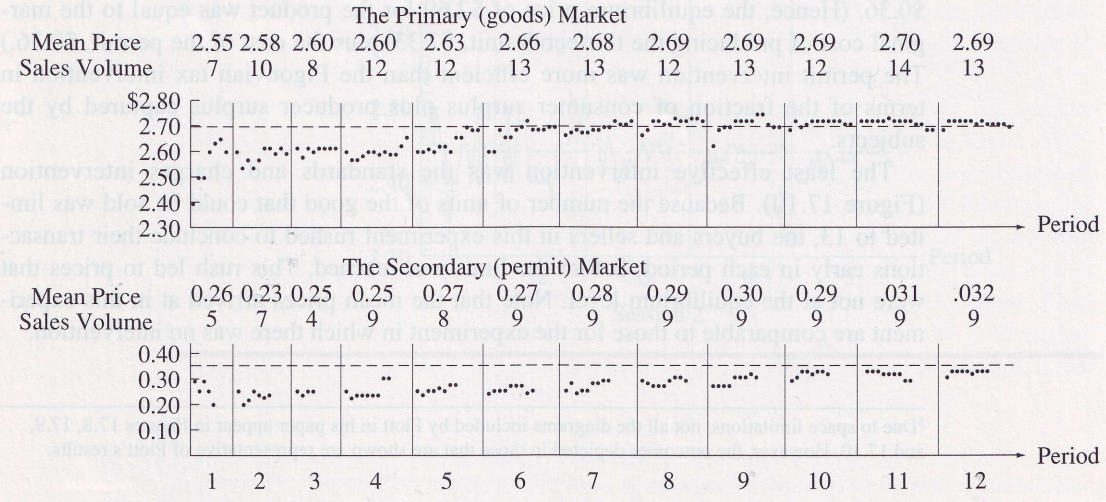
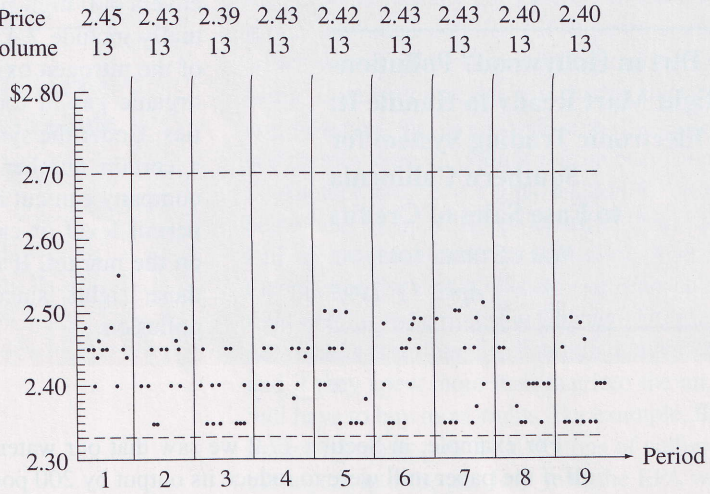


FIGURE 17.10 The results of Plott's experiments to evaluate the interventionist solutions to an externality: Standards.

The standards and charges intervention was the least effective of the three forms of intervention tested by Plott. It led to prices that were not at the optimal level for society.



17.5 A NONINTERVENTIONIST SOLUTION TO THE EXTERNALITY PROBLEM: THE COASIAN SOLUTION

Given our discussion thus far, it might appear that only through some sort of government intervention can our model society solve its externality problem. Naturally enough, the interventionists in our model society readily accept this idea. But the free-market advocates say "not so fast." Referring to the consulting report obtained in Section 17.2, they point out that Ronald Coase (an economist whose work we have already discussed several times) has developed a strong argument against the need for the interventionist solutions to the externality problem.

Coase argues that when an externality exists, the agents involved will be able to correct the effects of the externality by private agreement if they can costlessly negotiate among themselves.[6] The reason is simple. If the market has not determined a Pareto-optimal outcome, then, by definition, another outcome must exist that will make at least one of the parties (and perhaps all of them) better off without making any party worse off. Hence, if the agents simply talk with each other, they should be able to agree on a mutually beneficial way to split the gains that could be achieved by altering the market outcome to its Pareto-optimal level.

[6]Coase's views on the externality problem are presented in his seminal article "The Problem of Social Cost," *Journal of Law and Economics*, Vol. 3, 1960, pp. 1–44.

MEDIA NOTE POLLUTION RIGHTS MARKETS

Dirt in Hollywood? Pollution-Right Mart Ready to Handle It: Electronic Trading System for Southern California to Ease Sales of Credits

WALL STREET JOURNAL
April 12, 1995

In conjunction with the California Institute of Technology, the Pacific Stock Exchange created an electronic system for southern California pollution credits. The Regional Clean Air Incentives Market, or RECLAIM, covers 400 high-pollution firms and will eventually include 2,450 companies that emit most of the nitrogen oxide, sulfur oxide and reactive organic gas in four southern California counties. Under the system, each company is issued a certain number of permits to pollute. If a company can cut its emissions below its initial permit level, it can sell its remaining permits on the market. If it cannot, it will have to buy these rights since permits are required for pollution.

For example, in Section 17.2 we saw that our water-paper society would be better off if the paper mill were to reduce its output by 200 pounds. As we calculated, this reduction would cost the paper mill $1 in revenue, but it would save the water treatment plant $5 in costs. Clearly, both parties would be better off if they negotiate a deal in which the water treatment plant pays the mill to reduce its paper production. Because the paper mill stands to lose only $1 in revenue, any payment greater than $1 would make it better off. Furthermore, because the water treatment plant stands to save $5 if the mill makes the reduction, it should be willing to pay up to that amount to have the mill do so. Any payment from the water treatment plant to the paper mill that is greater than $1 but less than $5 will make both parties better off. Then, after the 200-pound reduction is negotiated, the two parties will want to see if a further reduction would be mutually beneficial. If so, they will continue their bargaining. According to Coase, the two parties will eventually arrive at a mutually beneficial solution that will also be Pareto-optimal for society.

However, what happens if the paper mill owns property rights allowing it to use the river for dumping wastes? Won't it simply ignore the offer made by the water treatment plant? Not at all, Coase would contend. As long as the mill is sufficiently compensated for reducing its output, doing so will make it better off even if it owns property rights that allow it to pollute the river. What if the situation is reversed and the water treatment plant owns the rights to use the river for whatever purposes it wants? Won't it simply forbid the mill to dump its wastes? Again, Coase would say no. In this case, the mill would be willing to pay the water treatment plant to allow it to dump its wastes as long as the mill's marginal revenues are greater than the marginal costs these wastes impose on the water treatment plant. Hence, no matter who owns the property rights to use the river, we will always arrive at a Pareto-optimal solution *if the parties can costlessly negotiate*. (Of course, we would expect the agent owning the property

MEDIA NOTE
POLLUTION RIGHTS MARKETS

Environmentalists Vie for Right to Pollute

WALL STREET JOURNAL
March 26, 1993

One possibly surprising result of the opening of the southern California market for pollution rights was the fact that the market received bids not only from power utilities, as it expected, but also from an environmentalist group called the National Healthy Air License Exchange. The group submitted bids for 1,100 permits, each of which would allow the owner to emit one ton of sulfur dioxide during the year. Rather than polluting, however, the group will retire these permits and thereby prevent pollution from occurring.

Another pollution rights auction is currently being held by the Chicago Board of Trade on behalf of the Environmental Protection Agency. In this market, the EPA will each year offer pollution right permits to be traded in Chicago. Utilities will get permits to pollute for a certain number of tons and if they spew more than that into the air, they will have to buy more rights. For example, Illinois Power currently puts 240,000 tons of sulfur dioxide a year into the air. This year, the EPA will restrict that, via permits, to 171,000 by giving them 171,000 tons. Illinois Power will have to buy rights for the rest at market prices. If environmentalist groups buy the rights instead, the power plant will either have to curtail its output or install scrubbers on its plant to reduce its pollution. In either case, the air will be cleaner.

rights to be able to negotiate the better deal, but that is a distribution issue, not an efficiency issue.)

Coase's views can be summarized in what has come to be known as the **Coase theorem:** *In markets with externalities, if property rights are assigned unambiguously and if the parties involved can negotiate costlessly, then the parties will arrive at a Pareto-optimal outcome regardless of which one owns the property rights.*

17.6 AN EVALUATION OF THE COASIAN SOLUTION: THE HOFFMAN-SPITZER EXPERIMENT

Basically, the Coasian solution to the externality problem rests on the idea that rational individuals in a situation where an externality exists will find a way to rectify the damage done by the externality if they are allowed to negotiate among themselves. To discover

TABLE 17.1 Payoff Schedule for the Hoffman-Spitzer Experiment

Row Number	Controller	Noncontroller
1	$ 0.00	$12.00
2	$ 4.00	$10.00
3	$ 6.00	$ 6.00
4	$ 8.00	$ 4.00
5	$ 9.00	$ 2.00
6	$10.00	$ 1.00
7	$11.00	$ 0.00

whether this would in fact happen, economist Elizabeth Hoffman and lawyer Matthew Spitzer performed the following experiment.[7]

The experimenters brought pairs of subjects into a room, one pair at a time. One of the subjects in the pair was designated the controller by the flip of a coin. The subjects were then given a payoff schedule like that shown in Table 17.1. The controller was told that she had two options. She could pick a row unilaterally, in which case she and her partner would receive the payoffs indicated. Alternatively, she and her partner could jointly select a row and then bargain as to how they would split the total payoff indicated in that row. Note that because the controller can affect the payoff received by her partner, her position is equivalent to that of an agent causing an externality.

Suppose that the controller unilaterally chooses row 7. In this case, she receives $11 and her partner receives nothing. The total payoff to the pair is $11. This choice is consistent with the competitive market outcome in a market with an externality.

Now let us assume that the controller selects row 2, which gives the pair a total payoff of $14. Because this is the highest possible total payoff, row 2 is the Pareto-optimal choice and the choice predicted by the Coase theorem. That is, from our discussion of the Coasian solution, we would expect the controller's partner to offer her sufficient compensation out of his payoff so that she will want to choose row 2.

The results of the experiment showed overwhelming support for the viability of the Coasian solution. Indeed, Hoffman and Spitzer found that only one of the 24 pairs of subjects who participated in this type of experiment failed to choose the Pareto-optimal outcome.

One aspect of the results was surprising, however. As we saw in Chapter 2, two fundamental assumptions of the free-market argument are that people are selfish and that they behave rationally when making economic decisions. Thus, we would expect that

[7]Actually, Hoffman and Spitzer performed a number of different experiments to investigate the Coase theorem. Information about these experiments can be found in Elizabeth Hoffman and Matthew Spitzer, "The Coase Theorem: Some Experimental Tests," *Journal of Law and Economics*, Vol. 25, 1982, pp. 93–98.

the controller would never agree to a split of the $14 that would give her less than the $11 she would receive by unilaterally choosing row 7. This did not turn out to be the case. Of the 24 subjects acting as controllers in this experiment, all but 7 agreed to an even split of the $14 between themselves and their partners so that each received $7. This finding would seem to challenge the assumptions of selfishness and rationality.

17.7 CONCLUSIONS

Our hypothetical society has once again struggled with a challenge to the free-market ideology of laissez-faire as it debated the proper response to the market failure caused by the externality problem. As is usually the case, the debate pitted interventionists, who feel government action is necessary to rectify the problem, against free-market advocates, who feel the problem can be rectified by market or quasi-market means. In the next chapter, this society will face an even more difficult challenge to the ideology of laissez-faire, the problem of public goods. The debate will again reflect the familiar party lines of the interventionists and the free-market advocates. This time, however, there will be no Coase theorem to remedy the problem, so some sort of intervention will seem inevitable.

17.8 SUMMARY

In this chapter, we have investigated externalities and how they can cause free markets to fail in determining optimal outcomes for society. The interventionists in our model society argued that government action was necessary and debated the most efficient way to intervene. The possibilities considered were Pigouvian taxes, standards and charges, and marketable permits. Based on the evidence of the Plott experiments, marketable permits appear to produce the best results. The free-market advocates in our model society relied on the famous Coase theorem to argue that government intervention was not necessary. Their position was that the market can rectify the problems caused by externalities if agents are free to negotiate costlessly. An experiment by Hoffman and Spitzer seems to support this view.

APPENDIX

EXCESS PRODUCTION UNDER EXTERNALITIES

In the presence of negative external effects, a firm would produce more than the socially optimal output level if (as is usually the case) it does not take the external effect into account. One way to rectify this antisocial behavior is to tax the firm on its output or require it to "buy" the right to produce the external effect.

To illustrate these ideas, consider two firms labelled 1 and 2 that produce goods 1 and 2 respectively. For simplicity assume that the firms act as perfect competitors in their respective product markets; thus firm 1 faces price p_1 for its output x_1 and firm 2 faces price p_2 for its output x_2.

Let $c_1(x_1)$ and $c_2(x_2)$ be the cost functions of the two firms. Further, let $e(x_1)$ be the external cost imposed on firm 2 by the production of x_1 by firm 1.

Then their profit functions are:

$$\pi_1 = p_1x_1 - c_1(x_1)$$
$$\pi_2 = p_2x_2 - c_2(x_2) - e(x_1)$$

The first order (profit-maximizing) conditions are:

$$p_1 = c_1'(x_1^*)$$
$$p_2 = c_2'(x_2^*)$$

that is, the firms set price = marginal cost, but firm 1 ignores the cost that it imposes on firm 2.

The socially solution is obtained by maximizing total profits jointly, that is,

$$\max_{\{x_1, x_2\}} W = (p_1x_1 - c_1(x_1)) + (p_2x_2 - c_2(x_2) - e(x_1))$$

The first order conditions of this problem yields:

$$p_1 = c_1'(x_1^S) + e'(x_1^S)$$
$$p_2 = c_2'(x_2^S)$$

Comparing the market solution and the social welfare solution, we see that firm 2 produces the socially optimal level of output $x_2^* = x_2^S$ but firm 1 produces too much; $x_1^* > x_1^S$. To see this more clearly in an example, assume that the cost functions are simple quadratic functions, viz.

$$c_1(x_1) = \frac{1}{2}c_1x_1^2$$

$$c_2(x_2) = \frac{1}{2}c_2x_2^2$$

$$e(x_1) = \frac{1}{2}ex_1^2$$

Then, $p_1 = c_1x_1^* \Rightarrow x_1^* = p_1/c_1$, while $p_1 = c_1x_1^S + ex_1^S = (c_1 + e)x_1^S \Rightarrow x_1^S = p_1/(c_1 + e)$. Hence,

$$x_1^* = \frac{c_1 + e}{c_1}\, x_1^S > x_1^S$$

In order to force firm 1 to produce the socially optimal output we can levy a tax on its output. Let the tax be $t(x_1)$. Then, with the tax firm 1 will maximize

$$\pi_1 = p_1x_1 - \frac{1}{2}c_1{x_1}^2 - t(x_1)$$

$$p_1 = c_1x_1^* + t'(x_1^*)$$

If a tax rate $t'(x_1) = ex_1$ is imposed, then in equilibrium,

$$p_1 = c_1x_1^* + ex_1^*$$

$$\Rightarrow x_1^* = x_1^S$$

Hence the total tax on firm 1 should be $\frac{1}{2}ex_1^2$, so in equilibrium, firm 1 pays $\frac{1}{2}e(x_1^*)^2$. In equilibrium, firm 2 incurs a cost of $\frac{1}{2}e(x_1^*)^2$ from the externality, so if the tax amount is transferred to firm 2, the externality is fully internalized. Such a tax is called a Pigouvian tax.

Markets for Externalities

As noted in the text, in practice such taxes are difficult to apply since they require the government or the regulatory body to know the exact cost function for the external cost. If the government knew the exact cost functions, it could simply calculate the equilibrium amounts and instruct the firms to produce accordingly.

A more practical alternative is to introduce a market for the externality. Let us say that firm 1 must "buy" the right to produce amount x_1 from firm 2 at price q—that is, firm 1 pays amount qx_1 to firm 2 to produce its output.

The profit functions in this case are:

$$\pi_1 = \max_{\{x_1\}} p_1 x_1 - c_1(x_1) - q x_{1\pi}$$

$$\pi_2 = \max_{\{x_2\}} p_2 x_2 - c_2(x_2) - e(x_1) + q x_1$$

where:

$$c_1(x_1) = \frac{1}{2} c_1 x_1^2$$

$$c_2(x_2) = \frac{1}{2} c_2 x_2^2$$

$$e(x_1) = \frac{1}{2} e x_1^2$$

Hence, firm 1 chooses output x_1, taking into account the cost qx_1 that it incurs by paying for the right to produce the externality, while firm 2 chooses output x_2 and the output x_1 it is willing to accept at price q. Finally, q is determined by market equilibrium.

The first order conditions are:

$$p_1 - q = c_1 x_1^* \quad \text{for firm 1}$$

$$p_2 = c_2 x_2^* \quad \text{and}$$

$$q = e x_1^* \quad \text{for firm 2}$$

In equilibrium,

$$\frac{p_1 - q}{c_1} = \frac{q}{e}$$

$$q = \frac{p_1 e}{c_1 + e}$$

The outputs of the firms are:

$$x_1^* = \frac{p_1}{c_1 + e}$$

$$x_2^* = \frac{p_2}{c_2}$$

which are the socially optimal quantities. Firm 1 pays the amount

$$q x_1^* = \frac{p_1^2 e}{(c_1 + e)^2}$$

EXERCISES AND PROBLEMS

1. Let us say that there is a class in which a weekly exam is given. The class has one genius, who always scores 100%, and 19 "regular" students, who always score 85%. The teacher grades the exam on a curve by taking the difference between the highest score and 100 and adding the result to each student's score. For example, if the highest score is 78, each student will have 22 points added to his or her score. The parents of these students pay them \$1 for each point scored on the exam.

   a. Does the genius impose externalities on the rest of the class? If so, what is the value of the marginal externality for each exam?

   b. What is the Pareto-optimal configuration of grades?

   c. If the highest scoring student on each exam could be taxed for each point he or she scores above the second highest scoring student, what marginal tax would result in the Pareto-optimal distribution of grades?

   d. If the 19 "regular" students were to bribe the genius to start scoring 85 instead of 100, what is the maximum amount of money they could offer?

2. A soot-spewing factory that produces steel windows is next to a laundry. We will assume that the factory faces a prevailing market price of $P = \$40$. Its cost function is $C = X^2$, where X is window output, so the factory's marginal cost is $MC = 2X$. The laundry produces clean wash, which it hangs out to dry. The soot from the window factory smudges the wash, so that the laundry has to clean it again. This increases the laundry's costs. In fact, the cost function of the laundry is $C = Y^2 + 0.05X$, where Y is pounds of laundry washed. The demand curve faced by the laundry is perfectly horizontal at a price of \$10 per pound.

   a. What outputs X and Y would maximize the sum of the profits of these two firms?

   b. Will those outputs be set by a competitive market?

   c. What per-unit tax would we need to set on window production to obtain the outputs found in Part a of this problem?

3. Suppose that the speed limit on a four-lane highway is 60 miles per hour. An accident has occurred in the southbound lanes, and people in the northbound lanes tend to slow down and look at it. This reduces the speed in the northbound lanes from 60 to 40 miles per hour. All the people in the northbound lanes are on their way to work and are driving 40 miles. If they agree not to slow down, they can get to work in 40 minutes. However, if they slow down, the trip will take 60 minutes. The people in the northbound lanes all obtain private satisfaction from slowing down and looking at the accident.

   a. Will an informal agreement not to slow down be stable?

   b. What is the externality in this situation?

4. Assume that a society has three firms, A, B, and C, situated in a row. The society faces the following problem. Every unit of output firm A produces creates a benefit for firm B of \$7 and a cost to firm C of \$3. The marginal cost of production for firm A is $MC = 4q^a$, where q^a is firm A's output. The market price for the output of firm A is \$16. (Assume that this is the marginal benefit to society of consuming each unit.)

   a. What total amount of output will firm A produce in a competitive market?

   b. What output is the optimal output for society?

   c. Suppose that firms A and B merge and then set the output that is best for them. What would that output be? Would it be the socially optimal output?

5. Let's say that there are three firms in a community that pollute the environment. The government has decided that 21 units of pollution must be abated and that each firm must cut pollution by 7 units. The marginal cost of pollution abatement is $MC^A = 1/3q$ for firm A, $MC^B = 1/2q$ for firm B, and $MC^C = 1/4q$ for firm C, where q is the quantity of abatement. The government wants the total amount of pollution to be reduced by 21 units and demands that each firm reduce its pollution by 7 units.

   a. Is this solution efficient? Explain why or why not.

   b. If the solution is not efficient, how much pollution should each firm produce at the efficient outcome?

   c. If each firm must abate 7 units of pollution, what is the maximum firm A would be willing to pay firm C to cut 2 additional units of pollution so that firm A could cut its pollution by only 5 units?