

Chapter 9

Externalities

9.1 Introduction

There is no consensus definition of an externality. I shall use the following definition.

Externality: An externality is present whenever the actions of a firm or consumer affect the economic well-being of another firm or consumer without compensation.

A classic example of an externality is water pollution. Consider a chicken farm that is located next to a river, upstream from a group of fishermen. Hauling waste products away from the farm is costly but dumping them in the river is free. The firm will therefore dump all of its waste into the river. The chicken waste will accumulate in the river and, eventually, cause the fish in the river to die. The farm's actions affect the livelihood of the fishermen who live downstream from the farm, but the farm doesn't compensate the fishermen—the farm is imposing a negative externality on the fishermen.

Externalities often occur when resources have no owner. The river in the example above has no owner so the cost to the firm of using it as a dump site is equal to zero. But the cost to society is not equal to zero; when the firm pollutes the river it damages the livelihood of the fishermen. As I will show later, the divergence between the price that the firm pays to use the river as an input—zero—and the marginal cost of the firm using the river will lead to an inefficient outcome.

Another example of an externality is air pollution. Suppose that a firm generates electricity by burning coal which creates pollution. It is costly to

filter the air before releasing it into the atmosphere but it is free to release it without filtering it (because no one owns the air). The firm therefore decides to release the air without filtering it. The air pollution accumulates and has unpleasant effects—such as acid rain—on consumers and other firms.

The two examples above concern negative externalities, but there are positive externalities as well. If I get a flu shot, it reduces your chance of getting the flu. However, since you won't compensate me for the benefit that you derive from my flu shot, I won't take that benefit into account when deciding whether to get a flu shot. Goods that generate positive externalities are often underconsumed because no compensation is provided to the consumer who generates the positive externality.

9.2 A Production Externality

I'll use air pollution as my example of an externality. Consider a firm that produces electricity. How does it choose its mix of labor and capital in the long-run? For a given output level, it chooses the combination of labor and capital that minimizes cost.

To find this optimal mix of inputs, the firm uses isocost lines. An isocost line shows all of the input mixes that cost the same amount. Denote the firm's capital input as K , the firm's labor input as L , the price of capital as P_K , and the price of labor as P_L . The total cost of inputs to the firm is then

$$TC = P_K K + P_L L \quad (9.1)$$

I can graph a firm's isocost lines by solving equation 9.1 for K .

$$K = \frac{TC}{P_K} - \frac{P_L}{P_K} L \quad (9.2)$$

The further an isocost line is from the origin, the greater the level of total cost it represents. For a given level of output, the firm therefore wants to choose the mix of inputs that is on the isocost line closest to the origin. This is the isocost line that is tangent to the production isoquant. Figure 9.1 shows a firm's optimal input mix if it wishes to produce one unit of output.

I shall now combine capital and labor into a composite input I and introduce a third input, air pollution. The firm will now choose between the composite input and air pollution in exactly the same way that it chose

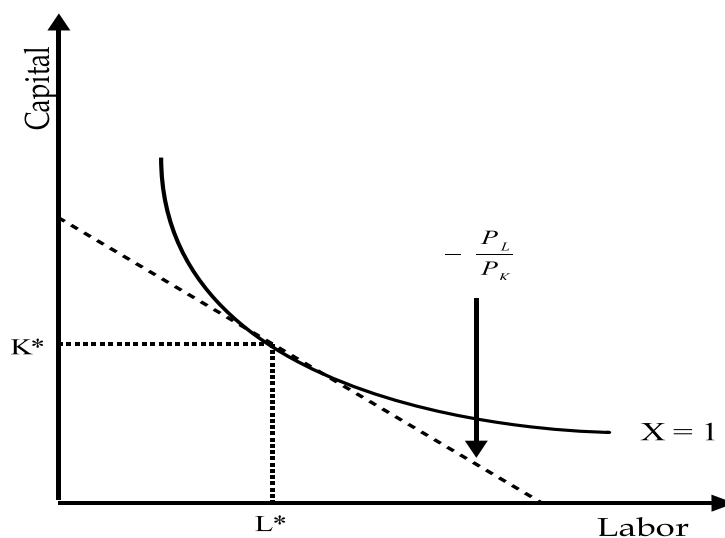


Figure 9.1: An Isoquant and Tangent Isocost Line

between capital and labor: it will choose the mix of air pollution and the composite input that minimizes its total cost.

If the price of air pollution P_{AP} is greater than zero the firm's isocost line is

$$AP = \frac{TC}{P_{AP}} - \frac{P_I}{P_{AP}}I \quad (9.3)$$

This isocost line is the slanted dotted line in figure 9.2. Faced with this isocost line, the firm will choose the mix of inputs given by point X .

If the price of air pollution is equal to zero the firm's total cost is

$$TC = P_I I \quad (9.4)$$

The firm will therefore ignore air pollution and choose the lowest possible level of the composite input. This mix of inputs is given by point Y in figure 9.2.

In practice, the air has no owner and the price of air pollution is therefore equal to zero. If a firm wishes to hire more labor, it must pay the owner of that labor. If it wishes to purchase more capital, it must pay the owner of the capital. But no one owns the air so the firm doesn't have to pay anyone

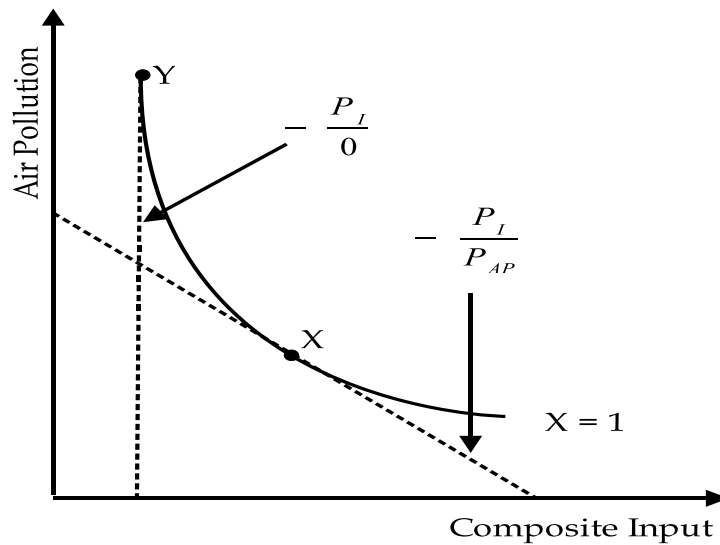


Figure 9.2: A Firm's Isoquant

for the right to pollute it. The result is that firms will not economize on air pollution and instead will make heavy use of it as an input.

If air pollution didn't generate an externality, this would not matter. The problem is that air pollution negatively affects the well-being and health of consumers. When firms pollute the air, they are imposing a negative externality on consumers. The price of air pollution to the firm may be equal to zero, but the cost of air pollution to society is not equal to zero.

The price that a firm pays to use air pollution as an input— P_{AP} —is equal to zero. The cost of air pollution is not equal to zero though because when the firm pollutes the air, it imposes a cost on consumers. The cost of air pollution is equal instead to the size of the negative externality imposed upon consumers. I shall denote the cost of the air pollution as $C_{AP} > 0$. The problem is illustrated in figure 9.3.

Line A is the isocost line to which the firm reacts. The price of air pollution is equal to zero so the total cost that the firm pays is

$$TC = P_I I \quad (9.5)$$

It therefore selects input mix (I_1, AP_1) , which uses the smallest possible amount of the composite input. However, because of the negative externality

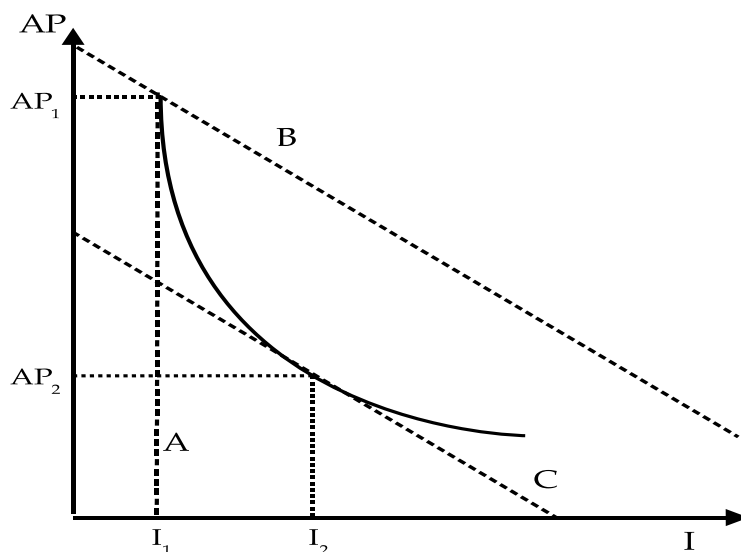


Figure 9.3: Three Isocost Lines

that air pollution creates, the total cost of the firm's output is actually equal to

$$TC = P_I I + C_{AP} AP \Rightarrow AP = \frac{TC}{C_{AP}} - \frac{P_I}{C_{AP}} I \quad (9.6)$$

Line *B* shows the true cost of the input mix that the firm has chosen. For the total cost function in equation 9.6, the minimum total cost is the input mix at the tangency between line *C* and the isoquant. This input mix uses I_2 units of the composite input and AP_2 units of air pollution.

9.3 Inefficiency due to an Externality

I will now compare the total costs implied by lines *A*, *B*, and *C*. I have shown that the true cost of the input mix (I_1, AP_1) is greater than the cost of the input mix (I_2, AP_2) . Thus,

$$TC_C < TC_B \quad (9.7)$$

Equation 9.7 says that the input mix that the firm selects is not the lowest cost input mix to society. Now compare line *A* to line *C*. Faced with line *A*,

the firm selects an input mix that uses little of the composite input I and a lot of air pollution. The cost to the firm of the input mix associated with line A is (recall that the price of air pollution to the firm is equal to zero):

$$TC_A = P_I I_1 \quad (9.8)$$

The cost of the input mix associated with line C to society is

$$TC_C = P_I I_2 + C_{AP} AP \quad (9.9)$$

Since I_1 is less than I_2 , it must be the case that TC_A is less than TC_C . Therefore,

$$TC_A < TC_C < TC_B \quad (9.10)$$

I shall now assume for simplicity that the firm has constant returns to scale and that the isoquant in figure 9.3 represents one unit of output. The marginal cost for each input mix is therefore equal to its total cost (to see why, ask yourself what the change in total cost will be if I increase output by one unit—this quantity is marginal cost). Thus,

$$MC_A < MC_C < MC_B \quad (9.11)$$

Equation 9.11 states that the marginal cost that the firm actually pays MC_A is less than the marginal cost to society MC_C that the firm would generate if it had to pay for the cost of the externality that its production generates. Further, MC_C is less than the marginal cost to society MC_B that the firm actually generates when it does not have to pay for the cost of the externality that its production generates.

I can use equation 9.11 to illustrate the inefficiency that results from the externality. In figure 9.4, D is the demand curve for electricity and the marginal cost curves are the marginal cost curves associated with isocost lines A , B , and C in figure 9.3. I shall assume that the electricity market is perfectly competitive, meaning that the marginal cost curves are also supply curves.

The price of air pollution is equal to zero, so the firm responds to the supply curve represented by MC_A . The equilibrium output of electricity is therefore E_A and the price of electricity is equal to P_A . At this output level, the marginal cost to society is MC_B . The marginal cost to the firm is

MC_A . The price of electricity does not equal the marginal cost to society of generating electricity, so the outcome is inefficient.

The efficient output of electricity is E_C . At this output level, the price of electricity is equal to the marginal cost to society of generating electricity. Comparing equilibria E_A and E_C shows that too much electricity is produced at too high a marginal cost (and too low a price) when air pollution's price is equal to zero.

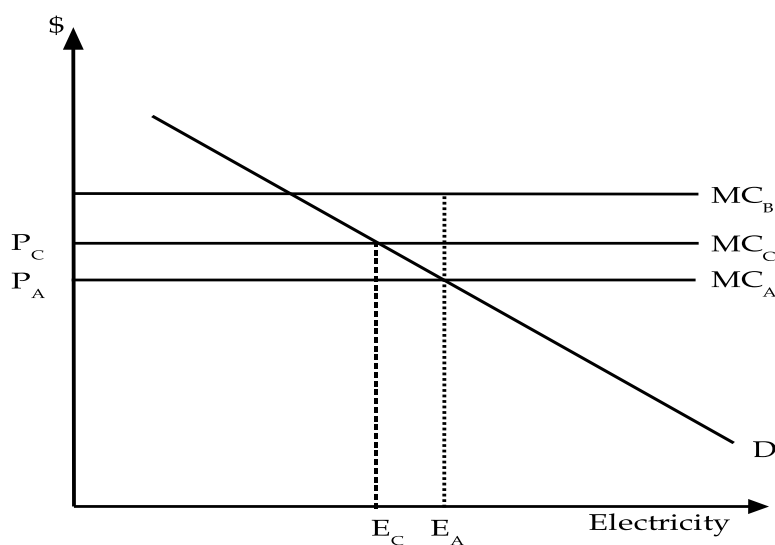


Figure 9.4: Supply and Demand for Electricity

9.4 Policy Options

9.4.1 Mandatory Reductions in Pollution

Suppose that the government observes that pollution levels are high and decides to act. It orders all firms to reduce their pollution by an amount R_G . Figure 9.5 shows the impact on two firms that use different technologies to produce electricity. It depicts the marginal cost to each firm of reducing pollution, where R denotes pollution reduction. As you can see, the marginal cost for firm one to reduce pollution is higher than the marginal cost for firm two.

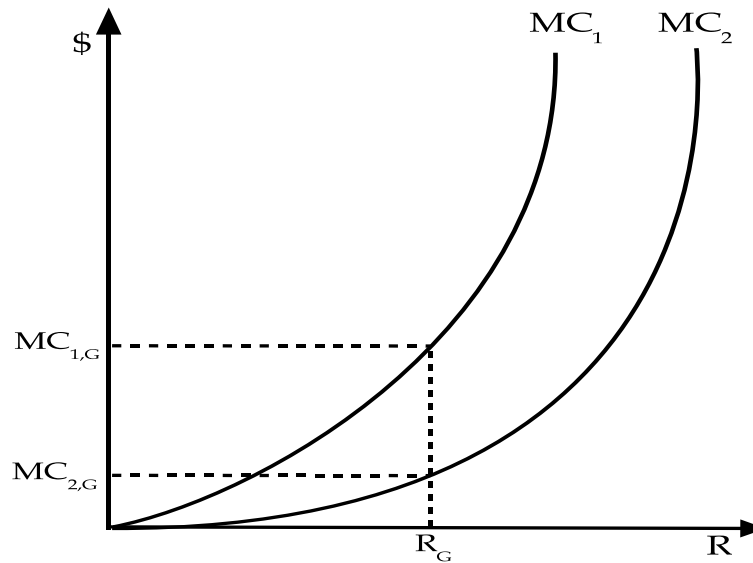


Figure 9.5: Two Firm's with Different Costs of Reducing Pollution

Is the government's policy the best way to reduce pollution? Well, a minimum standard for a pollution reduction program is that it minimize total cost for a given level of pollution reduction. The solution in figure 9.5 does not meet this standard.

Figure 9.6 shows an alternate plan that reduces total pollution by the same amount at a lower total cost. Firm one reduces its pollution reduction by one unit (from R_G to $R_{1,T}$) while firm two increases its pollution reduction by one unit (from R_G to $R_{2,T}$), leaving total pollution reduction unchanged. The total cost is lower though because at R_G firm two's marginal cost of reducing pollution is lower than firm one's marginal cost of reducing production. I've exchanged a costly unit of pollution reduction (i.e., the unit that firm one was producing) for a less expensive unit of pollution reduction (i.e., the additional unit that firm two produces).

There are two problems with the trade that I have made. First, I have increased the total cost to firm two, which must now do more of the pollution reduction, and reduced the total cost to firm one, which must now do less of the pollution reduction—I have rewarded the inefficient firm and penalized the efficient firm. Second, to make this trade I must know the marginal cost curves for both firms. This is information that the government is unlikely to

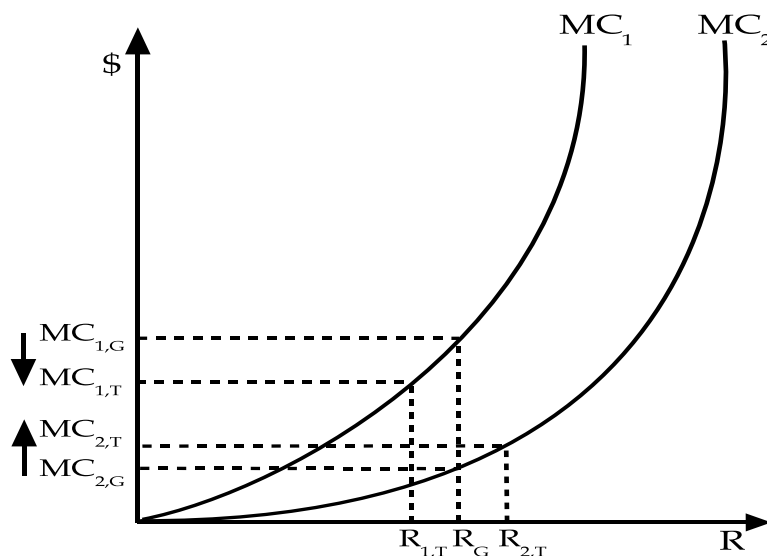


Figure 9.6: A Reduction in the Total Cost of Reducing Pollution

have.

9.4.2 Transferable Pollution Rights

A solution to these problems is transferable pollution rights. Under transferable pollution rights, each firm has the right to pollute a fixed amount and firms are allowed to trade their pollution rights with one another. That is, a firm can sell to another firm the right to emit X units of pollution. If a firm makes such a sale, it must increase its pollution reduction by X units since it no longer has the right to emit those X units of pollution.

Two firms will make such a transaction if their marginal costs of reducing pollution are different. To see why, consider a price (per unit of pollution right) that is between the marginal costs of the firms. At this price, the low cost can firm sell a pollution unit for more than it costs it to reduce pollution by one unit. The high cost firm, meanwhile, can pay less for the right to pollute one unit than it is currently paying to reduce its last unit of pollution. Thus, the trade increases both firms' profits.

Consider, for example, figure 9.6. Assume that at R_G both firms are using their full allocation of pollution rights. Then it is an mutually beneficial

trade for firm two to sell one unit of its pollution rights to firm one. Firm two must therefore increase its pollution reduction by one unit while firm one can decrease its pollution reduction by one unit. This transaction makes both firms better off without changing the total amount of pollution reduction. In addition, it does not penalize firm two—and efficient firms in general—since firm two can sell its pollution rights to a less efficient firm and increase its total profit. Under this system, firm two will sell pollution rights to firm one until the marginal cost of reducing pollution is equal for both firms. This is the lowest cost at which the government's desired pollution reduction can be done.

9.4.3 Effluent Fees

Another possible solution to the problem of pollution is to charge firms a price P_{AP} for every unit of pollution that they create¹. This strategy, known as effluent fees, is shown in figure 9.7. Firms will choose to reduce pollution up until the point where the marginal cost of reducing pollution equals the price of a unit of pollution. Why? Because when $MC < P$ it is cheaper to reduce pollution than to pay the effluent fee. When $MC > P$, on the other hand, it is cheaper to pay the effluent fee.

In figure 9.7, both firms' production generates P units of pollution. Firm one reduces pollution by R_1 units and pays P_{AP} for the remaining $P - R_1$ units of pollution that it generates. Firm two reduces pollution by R_2 units and pays P_{AP} for the remaining $P - R_2$ units of pollution that it generates.

Effluent fees have a major drawback: unless the government knows each firm's marginal cost curve, it cannot predict how much pollution reduction each firm will undertake. It cannot therefore choose the total amount of pollution reduction that will be done. By changing the price P_{AP} over time and observing the amount of pollution that firm's generate though, the government can eventually achieve its desired level of pollution reduction.

An advantage of effluent fees is that they generate revenue for the government. This revenue can be used to mitigate the effects of air pollution on consumers and firms. Another advantage is that effluent fees, like transferable pollution rights, reward efficient firms, as shown in figure 9.7. If both firms pollute the same amount P , firm one pays the area $0-A-C-P$ in effluent fees and pollution reduction. Firm two pays the area $0-B-C-P$. The more

¹Of course, to be effective, P_{AP} must be greater than zero

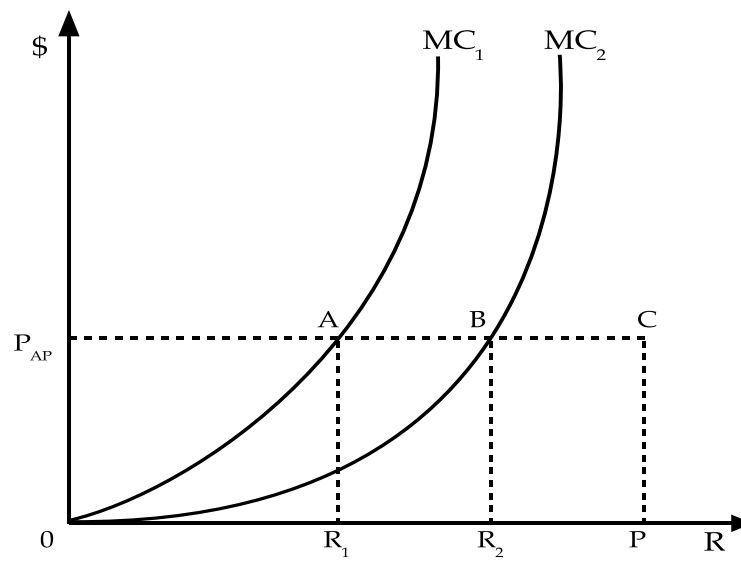


Figure 9.7: Effluent Fees

efficient firm—firm two—pays less and so has a higher total profit (all other things being equal).