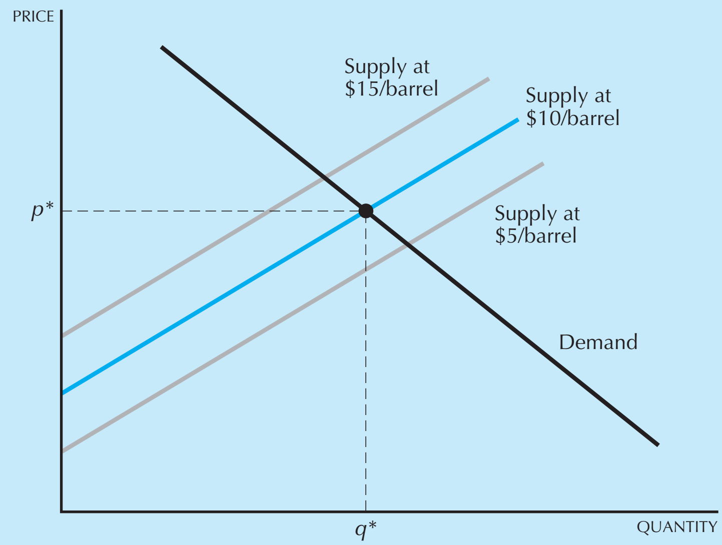


Figure 24.9

The entitlement program. Under the entitlement program the supply curve of gasoline would lie between the supply curve if all oil were provided at the imported price and the supply curve if all oil were provided at the domestic price.

discouraged production of domestic oil, and thereby increases the price of gasoline, but this was apparently acceptable to Congress at the time.

24.11 Carbon Tax Versus Cap and Trade

Motivated by concerns about global warming, several climatologists have urged governments to institute policies to reduce carbon emissions. Two of these reduction policies are particularly interesting from an economic point of view: **carbon taxes** and **cap and trade**.

A carbon tax imposes a tax on carbon emissions, while a cap and trade system grants licenses to emit carbon that can be traded on an organized market. To see how these systems compare, let us examine a simple model.

Optimal Production of Emissions

We begin by examining the problem of producing a target amount of emissions in the least costly way. Suppose that there are two firms that have

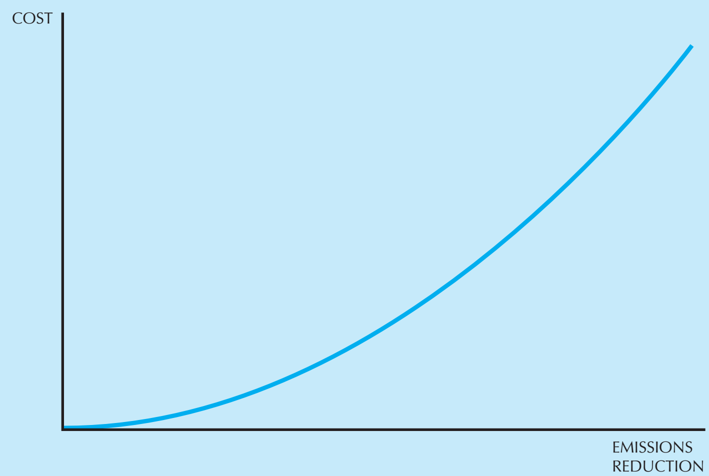


Figure 24.10 **Cost function for emissions.** The curve shows the cost associated with emission reductions.

current levels of carbon emissions denoted by $(\overline{x}_1, \overline{x}_2)$. Firm i can reduce its level of emissions by x_i at a cost of $c_i(x_i)$. Figure 24.10 shows a possible shape for this cost function.

The goal is to reduce emissions by some target amount, T, in the least costly way. This minimization problem can be written as

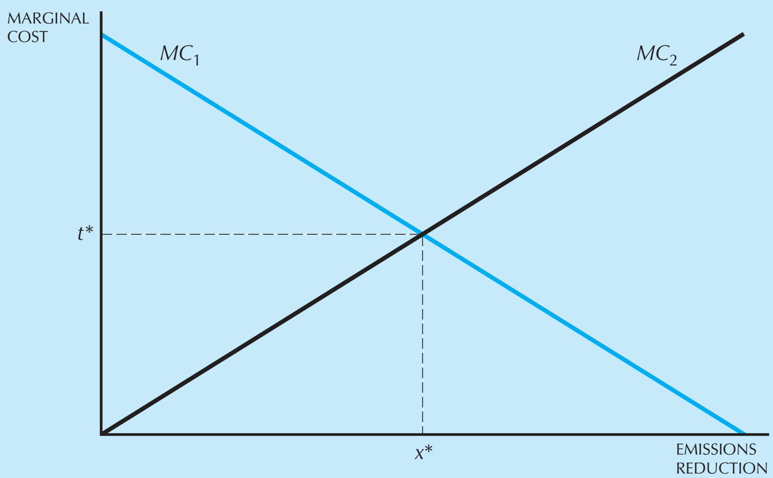
$$\min_{x_1,x_2} c_1(x_1) + c_2(x_2)$$
$$\text{such that } x_1 + x_2 = T.$$

If it knew the cost functions, the government could, in principle, solve this optimization problem and assign a specific amount of emission reductions to each firm. However, this is impractical if there are thousands of carbon emitters. The challenge is to find a decentralized, market-based way of achieving the optimal solution.

Let us examine the structure of the optimization problem. It is clear that at the optimal solution the marginal cost of reducing emissions must be the same for each firm. Otherwise it would pay to increase emissions in the firm with the lower marginal cost and decrease emissions in the firm with the higher marginal cost. This would keep the total output at the target level while reducing costs.

Hence we have a simple principle: at the optimal solution, the marginal cost of emissions reduction should be the same for every firm. In the two-firm case we are examining, we can find this optimal point using a simple diagram. Let $MC_1(x_1)$ be the marginal cost of reducing emissions by x_1

for firm 1 and write the marginal cost of emission-reduction for firm 2 as a function of firm 1's output: $MC_2(T - x_1)$, assuming the target is met. We plot these two curves in Figure 24.11. The point where they intersect determines the optimal division of emission reductions between the two firms given that T emission reductions are to be produced in total.



Equilibrium in the cap and trade market. The point t^* gives the optimal carbon tax and emissions license price.

Figure 24.11

A Carbon Tax

Instead of solving for the cost-minimizing solution directly, let us instead consider a decentralized solution using a carbon tax. In this framework, the government sets a tax rate t that it charges for carbon emissions.

If firm 1 starts with $\overline{x}_1$ and reduces its emissions by x_1, then it ends up with $\overline{x}_1 - x_1$ emissions. If it pays t per unit emitted, its carbon tax bill would be $t(\overline{x}_1 - x_1)$.

Faced with this tax, firm 1 would want to choose that level of emission reductions that minimized its total cost of operation: the cost of reducing emissions plus the cost of paying the carbon tax on the emissions that remain. This leads to the cost minimization problem

$$\min_{x_1} c_1(x_1) + t(\overline{x}_1 - x_1).$$

Clearly the firm will want to reduce emissions up to the point where the marginal cost of further reductions just equals the carbon tax, i.e., where $t = MC_1(x_1)$.

If the carbon tax is set to be the rate t^*, as determined in Figure 24.11, then the total amount of carbon emissions will be the targeted amount, T. Thus the carbon tax gives a decentralized way to achieve the optimal outcome.

Cap and Trade

Suppose, alternatively that there is no carbon tax, but that the government issues tradable **emissions licenses**. Each license allows the firm that holds it to produce a certain amount of carbon emissions. The government chooses the number of emissions licenses to achieve the target reduction.

We imagine a market in these licenses so each firm can buy a license to emit x units of carbon at a price of p per unit. The cost to firm 1 of reducing its emissions by x_1 is $c_1(x_1) + p(\overline{x}_1 - x_1)$. Clearly the firm will want to operate where the price of an emissions license equals the marginal cost, $p = MC_1(x_1)$. That is, it will choose the level of emissions at the point where the cost of reducing carbon emissions by one unit would just equal the cost saved by not having to purchase a license.

Hence the marginal cost curve gives us the supply of emissions as a function of the price. The equilibrium price is the price where the total supply of emissions equals the target amount T. The associated price is the same as the optimal carbon tax rate t^* in Figure 24.11.

The question that remains is how to distribute the licenses. One way would be to have the government sell the licenses to firms. This is essentially the same as the carbon tax system. The government could pick a price and sell however many licenses are demanded at that price. Alternatively, it could pick a target level of emissions and auction off permits, letting the firms themselves determine a price. This is one type of "cap and trade" system. Both of these policies should lead to essentially the same market-clearing price.

Another possibility would be for the government to hand out the licenses to the firms according to some formula. This formula could be based on a variety of criteria, but presumably an important reason to award these valuable permits would be building political support for the program. Permits might be handed out based on objective criteria, such as which firms have the most employees, or they might be handed out based on which firms have donated the most to some political causes.

From the economic point of view, it doesn't matter whether the government owns the licenses and sells them to the firms (which is basically a carbon tax system) or whether the firms are given the licenses and sell them to each other (which is basically cap and trade).

If a cap and trade system is created, firms will find it attractive to invest in ways to acquire the emission permits. For example, they would want to lobby Congress for such licenses. These lobbying expenditures should be counted as part of the cost of the system, as described in our earlier discussion of **rent seeking**. Of course, the carbon tax system would also be subject to similar lobbying. Firms would undoubtedly seek special carbon tax exemptions for one reason or another, but it has been argued that the carbon tax system is less susceptible to political manipulation than a cap and trade system.

Summary

1. The short-run supply curve of an industry is just the horizontal sum of the supply curves of the individual firms in that industry.

2. The long-run supply curve of an industry must take into account the exit and entry of firms in the industry.

3. If there is free entry and exit, then the long-run equilibrium will involve the maximum number of firms consistent with nonnegative profits. This means that the long-run supply curve will be essentially horizontal at a price equal to the minimum average cost.

4. If there are forces preventing the entry of firms into a profitable industry, the factors that prevent entry will earn economic rents. The rent earned is determined by the price of the output of the industry.

REVIEW QUESTIONS

1. If $S_1(p) = p-10$ and $S_2(p) = p-15$, then at what price does the industry supply curve have a kink in it?

2. In the short run the demand for cigarettes is totally inelastic. In the long run, suppose that it is perfectly elastic. What is the impact of a cigarette tax on the price that consumers pay in the short run and in the long run?

3. True or false? Convenience stores near the campus have high prices because they have to pay high rents.

4. True or false? In long-run industry equilibrium no firm will be losing money.

5. According to the model presented in this chapter, what determines the amount of entry or exit a given industry experiences?

6. The model of entry presented in this chapter implies that the more firms in a given industry, the (steeper, flatter) is the long-run industry supply curve.