Chapter 12

Incentive-Based Strategies: Emission Charges and Subsidies

In the last chapter we discussed some of the advantages and disadvantages of using a standards approach to pollution control. Although standards seemingly offer direct control of polluting activities, in many applications they have serious drawbacks by virtue of their tendency to treat all sources alike even though they may be very different, and to lock in certain technologies. A major problem is that they typically are unable to take advantage of the private information that polluters have about means and procedures they could use to reduce pollution. **Incentive-based** (IB) environmental policies are designed to rectify these drawbacks. IB plans work by having public authorities first set overall objectives and rules, and then leaving firms enough latitude that their normal commercial incentives will lead to the adoption of cost-effective pollution-control procedures and technologies.

There are basically two types of incentive policies:

1. **charges and subsidies** and
2. **transferable discharge permits.**

Both require centralized policy initiative to get started but rely on flexible firm responses to attain efficient pollution control. In the first, firms are given latitude to respond however they wish to what is essentially a new price for using the services of the environment. The second is designed to work more or less automatically through the interactions among polluters themselves or between polluters and other interested parties. In recent years many countries, including the United States, have introduced programs of transferable discharge permits, also called **market-based** incentive programs. In Europe, many countries have relied upon environmental charges to motivate emission reductions, as well as raise public revenues. Exhibit 12.1 notes some of the plans adopted in Europe. In this chapter

Green Taxes in Europe — EXHIBIT 12.1

Since the early 1990s, many countries in Europe have introduced green taxes on emissions directly or on activities and/or products that contribute to emissions.

The vast majority of these are taxes on motor fuels. The original justification of these taxes was to raise revenues; more recently they are aimed at reducing fuel use and carbon dioxide (CO_2) emissions. But numerous other environmental taxes have been started. Many countries now have taxes on nitrous oxide (NO_x) emissions. Denmark and Norway, as well as the United States, have taxes on ozone-depleting substances. Numerous taxes exist on solid-waste materials destined for landfills and specific items such as batteries and cameras. Norway in 2004 introduced a tax on mercury releases from landfills; Denmark in 2005 introduced a tax on phosphorus. Various taxes have also been started on pesticides and fertilizer uses.

European countries have been active in introducing taxes on emissions of greenhouse gases, particularly CO_2. Finland was one of the first to do this, with revenues used partly to offset taxes on employment. Sweden introduced CO_2 taxes in 1991, as did Switzerland in 2008, and Ireland introduced a carbon tax around the same time. In France an effort was made to introduce a broad tax on CO_2 emissions, but it ran into a common implementation problem: so many exemptions for specific industries (especially agriculture) that it was never instituted.

Sources: Organization for Economic Cooperation and Development, *Environmentally Related Taxes in OECD Countries: Issues and Strategies* (2001); *Instrument Mixes Addressing Mercury Emissions to Air* (2004); *Instrument Mixes Addressing Non-Point Sources of Water Pollution* (2005); *The Political Economy of the Norwegian Aviation Fuel Tax* (2005); *The United Kingdom Climate Change Levy* (2004); *Taxation, Innovation and the Environment*, (2010).

we examine the economics of emission charges and subsidies. In the next chapter we will consider the technique of transferable discharge permits.

Environmental economists have long favored the idea of incorporating incentive-based policies more thoroughly into environmental policies. These can serve to put more teeth into environmental policies in many cases and substantially improve the cost-effectiveness of these policies. But keep in mind something said before: No single type of policy is likely to be the best in all circumstances. Incentive-based policies are no exception. They have strengths and they have weaknesses. The strengths are sufficiently strong to encourage greater reliance on them in many circumstances. But there are many types of environmental problems where they may not be as useful as other approaches.

Emission Charges

Firms pollute because they do not take into account the social damage their actions cause. Thus, the most straightforward approach to controlling emissions is for authorities to charge a price for these emissions. This can be done in two ways: by charging for each unit of emissions or by giving a subsidy for each unit of emissions that the source cuts back.

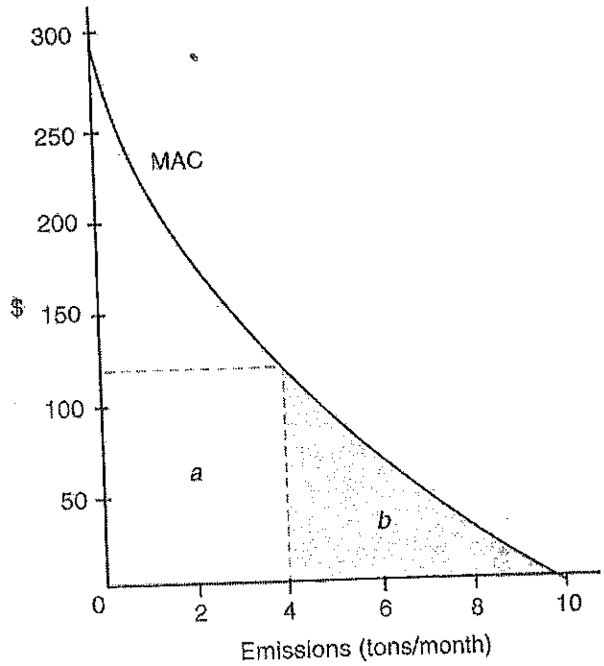
We deal first with **emission charges**, sometimes also called **"emission taxes."** In a charge system polluters are told: "You may discharge any amount of residuals you wish, but your emissions will be measured and you will be required to pay a certain charge for every unit (e.g., ton) of effluent you discharge." For example, one of the first emission charges proposed in the United States was in 1970, when President Nixon recommended a tax of 15 cents per pound on sulfur emissions from large power plants. It was never adopted. When an emission charge is put into effect, firms responsible for emissions must essentially pay for the services of the environment—transportation, dilution, chemical decomposition, and so on—just as they must pay for all other inputs used in their operations. And just as they have always had an incentive to conserve on scarce labor and other conventional production inputs, they will now have an incentive to conserve on their use of environmental services. How do they do this? Any way they wish (within reason). This may sound flippant but in fact it represents the main advantage of this technique. By leaving polluters free to determine how best to reduce emissions, this type of policy attempts to harness their own energy and creativity and their desire to minimize costs, to find the least-cost way of reducing emissions. It could be any combination of treatment, internal process changes, changes in inputs, recycling, shifts to less polluting outputs, and so on. The essence of the charge approach is to provide an incentive for the polluters themselves to find the best way to reduce emissions, rather than having a central authority determine how it should be done. And in so doing, they will have a strong incentive to use the private information they have about the pollution-control costs of alternative technologies.

The Basic Economics

The essential mechanics of an emission charge are depicted in Figure 12.1. The numbers refer to a single source of a particular pollutant. The top panel shows the analysis numerically, while the bottom shows essentially the same information graphically. The tax has been set at $120/ton/month. The second column in the top panel shows the firm's marginal abatement costs and the third column shows total abatement costs. The last two columns show the total monthly tax bill the firm would pay at different emission levels, and the total cost, consisting of the sum of abatement costs and the tax bill. We see that the minimum total cost of $855 occurs at an emission rate of 4 tons/month. Let's pursue the logic of this by considering marginal abatement costs. Suppose the firm is initially emitting 10 tons/month; if it were to cut emissions to 9 tons, it would cost $15 in abatement costs, but it would save $120 in total tax bill, clearly a good move. Following this logic, it could improve its bottom line by continuing to reduce emissions as long as the tax rate is above marginal abatement costs. The rule for the firm to follow is thus: Reduce emissions until marginal abatement costs are equal to the charge on emissions. This is shown diagrammatically in the bottom part of Figure 12.1. With a continuous marginal abatement cost function, it's possible to talk about fractions of tons of emissions, something we could not do in the upper panel. So the graph is drawn to agree with the integer values above; that is, the charge of $120 leads the firm to reduce emissions to exactly 4 tons/month.

FIGURE 12.1 An Emissions Charge

Emissions (tons/month)	Marginal Abatement Cost	Total Abatement Cost	Total Tax Bill at $120/Ton	Total Costs
10	0	0	1,200	1,200
9	15	15	1,080	1,095
8	30	45	960	1,005
7	50	95	840	935
6	70	165	720	885
5	95	260	600	860
4	120	375	480	855
3	150	525	360	885
2	185	710	240	950
1	230	940	120	1,060
0	290	1,230	0	1,230



After the firm has reduced its emissions to 4 tons/month, its total (monthly) tax bill will be $480. Its monthly abatement costs will be $375. Graphically, total abatement costs correspond to the area under the marginal abatement cost function, labeled *b* in the figure. The total tax bill is equal to emissions times the tax rate, or the rectangle labeled *a*. Under a charge system of this type, a firm's total cost equals its abatement costs plus the tax payments to the taxing authority.

Why wouldn't the firm simply disregard the charge, continue to pollute as it has been doing, and just pass the charge on to consumers in the form of higher prices? If the firm stayed at 10 tons of emissions, its total outlay would be $1,200/month, consisting entirely of tax payment. This is much higher than the $855 it can achieve by cutting back to 4 tons/month. The assumption in an emissions charge program is that **competitive pressures** will lead firms to do whatever they can to minimize their costs. Thus, when there is competition in the industry subject to the emission tax, it will lead firms to reduce emissions in response to the tax. By the same token, however, we must recognize that if competition is weak, firms may not respond in this way. Electric power plants, for example, are usually operated by regulated monopolies subject to oversight by public utility commissions. They may not respond to charges on sulfur dioxide (SO_2) emissions in the same way as firms that operate in more competitive economic climates.

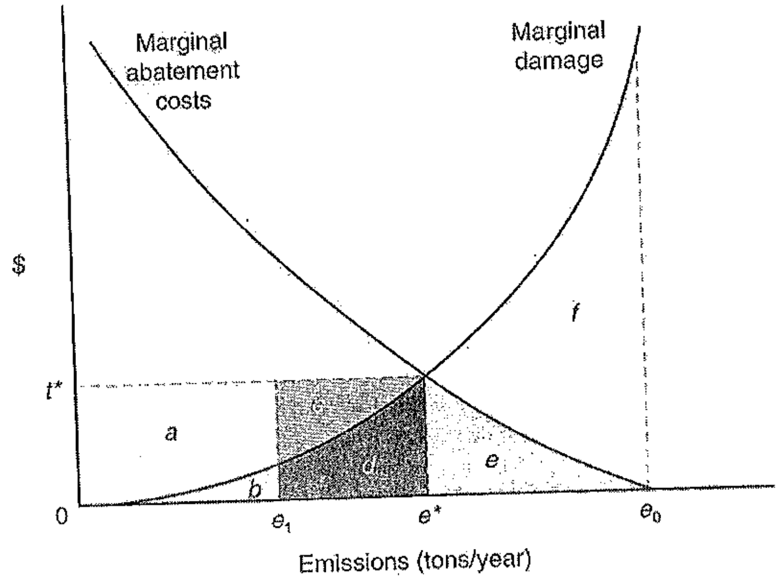
For competitive firms, the amount of the response will depend on several factors. The higher the charge, the greater the reduction, and vice versa. In the example of Figure 12.1, a tax of $50 would have led the source to reduce emissions only to 7 tons/month, whereas one of $180 would have produced a cutback to 2 tons/month; that is, the firm would select an emissions quantity closest to where MAC equals the charge. Also, the steeper the marginal abatement cost function, the less emissions will be reduced in response to a tax. We will come back to this later.

Compare the charge approach with an emission standard. With the tax the firm's total outlay is $855. Suppose that, instead, the authorities had relied on an emission standard to get the firm to reduce emissions to 4 tons/month. In that case the firm's total outlay would be only the $375 of abatement costs. Thus, the charge system ends up costing the firm more than the standards approach. With a standard, the firm has the same total abatement costs as in the charge system, but it is still essentially getting the services of the environment free, whereas with a charge system it has to pay for those services. But although polluting firms would thus prefer standards to emission charges, there are good reasons, as we shall see, why society would often prefer charges over standards.

The Level of the Charge

In competitive situations, higher charges will bring about greater reductions in emissions, but just how high should the charge be set? If we know the marginal damage function, the answer presumably would be to set the charge so as to produce the efficient level of emissions, as in Figure 12.2. At a charge rate of t^*, emissions are e^*, and marginal damages equal marginal abatement costs. The firm's total costs of emission control are divided into two types: total abatement costs (compliance costs) of e and total tax payments of $(a + b + c + d)$. The former are the costs of whatever techniques the firm has chosen to reduce emissions from e_0 to e^*, whereas the latter are payments to the control agency covering the charge on the remaining emissions. From the standpoint of the firm, of course, these are both real costs that will have to be covered out of revenues. From the standpoint of *society*, however, the tax payments are

FIGURE 12.2 An Efficient Emission Charge



different from the abatement costs. Whereas the latter involve real resources and therefore real social costs, the emission charges are actually **transfer payments**, payments made by the firms (ultimately by people who buy the firms' output) to the public sector and eventually to those in society who are benefited by the resulting public expenditures. When a firm considers its costs, it will include both abatement costs and tax payments; when considering the social costs of a tax program, it is appropriate to exclude transfer payments.

The reduction of emissions from e_0 to e^* has eliminated damages of $(e + f)$. Remaining damages are $(b + d)$, an amount less than the firm pays in taxes. This underscores the idea that the emission charge is based on the right to use environmental resources, not on the notion of compensation. But a "flat tax" like this (one tax rate for all emissions) has been criticized because it would often lead to situations where the total tax payments of firms would substantially exceed remaining damages. A way around this is to institute a **two-part emission charge.** We allow some initial quantity of emission to go untaxed, applying the charge only to emissions in excess of this threshold. For example, in Figure 12.2 we might allow the firm e_1 units of emissions free of tax and apply the tax rate of t^* to anything over this. In this way the firm would still have the incentive to reduce emissions to e^*, but its total tax payments would be only $(c + d)$. Total abatement costs, and total damages caused by the e^* units of emissions, would still be the same.

How might the charge be set if regulators did not know the marginal damage function? Emissions are connected to ambient quality; the lower the emissions the lower the ambient concentration of the pollutant, in general. So one strategy might be to set a tax and then watch carefully to see what this did in terms of improving ambient quality levels. We would have to wait long enough to give firms time to respond to the tax. If ambient quality does not improve as much as desired, increase the charge; if ambient quality improves more than is thought appropriate, lower the charge. This is a successive approximation process of finding the correct long-run emissions charge. It is not at all clear whether this approach would be practicable in the real world. In responding to a charge, polluters would invest in a variety of pollution-control devices and practices, many of which would have relatively high up-front costs. This investment process could be substantially upset if, shortly afterward, the authorities shift to a new tax rate. Any agency trying to use this method to find the efficient charge rate would undoubtedly find itself embroiled in a brisk political battle. Rather than planning to make successive adjustments in the tax rate, there would be a strong incentive for policymakers to determine the correct rate at the beginning. This would put a premium on prior study to get some idea of the shapes of the aggregate abatement and damage cost curves.

Emission Charges and Cost-Effectiveness

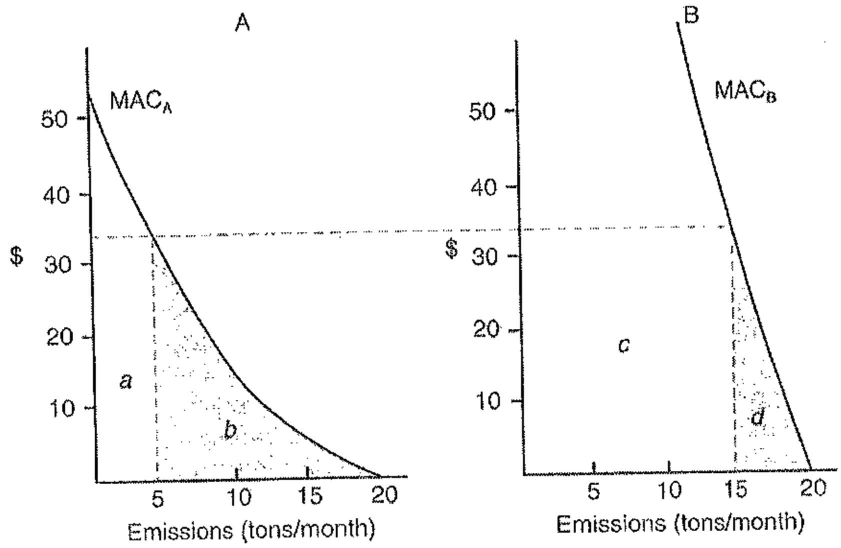
Perhaps the strongest case for a policy of effluent charges is to be made on grounds of their effects in controlling multiple sources of emissions in a way that satisfies the **equimarginal principle.** If the same tax rate is applied to different sources with different marginal abatement cost functions, and each source reduces its emissions until its marginal abatement costs equal the tax, then marginal abatement costs will automatically be equalized across all the sources.

This is depicted in Figure 12.3.[1] We assume here that there are two sources of a particular type of emission, labeled Source A and Source B. Also assume that these emissions, after they leave the respective sources, are uniformly mixed together, so that the emissions of the two plants are equally damaging in the downstream, or downwind, impact area. The marginal abatement costs for the two sources are the same as those we used in the last chapter. They are shown in graphical form at the bottom of Figure 12.3. The marginal abatement costs of Source A increase much less rapidly with reductions in emissions than do those of Source B. In the real world, differences like this are normally related to the fact that the firms are using different production technologies. They may be producing different outputs (e.g., a pulp mill and a food-canning firm), or they may be plants in the same industry but using different production techniques (e.g., coal-fired and oil-fired electric power plants). According to the graphs, the production technology used by Source B makes emission reduction more costly than it is at Source A. If we impose an effluent charge of $33/ton on each source, the operators of Source A will reduce their emissions to 5 tons/month; those at Source B will cut back to 15 tons/month (dealing only with integer values). After these reductions, the two sources will have the same marginal abatement costs. The total reduction has

[1] We have seen a graph like this several times before, for example, in Figures 11.3 and 5.5.

FIGURE 12.3 Emission Charges and the Equimarginal Rule

	Marginal Abatement Costs	
Emission Level (tons/month)	Source A	Source B
20	0.0	0.0
19	1.0	2.1
18	2.1	4.6
17	3.3	9.4
16	4.6	19.3
15	6.0	32.5
14	7.6	54.9
13	9.4	82.9
12	11.5	116.9
11	13.9	156.9
10	16.5	204.9
9	19.3	264.9
8	22.3	332.9
7	25.5	406.9
6	28.9	487.0
5	32.5	577.0
4	36.3	677.2
3	40.5	787.2
2	44.9	907.2
1	49.7	1,037.2
0	54.9	1,187.2



been 20 tons per month, which the effluent charge has automatically distributed between the two firms in accordance with the equimarginal principle.

Note very carefully that the emission tax has led Source A to reduce its emissions by 75 percent, whereas Source B has reduced its emissions by only 25 percent. The emissions tax leads to larger proportionate emission reductions from firms with lower marginal abatement costs. Conversely, firms having steeper marginal abatement costs will reduce emissions less, in proportionate terms. Suppose that instead of the charge the authorities had instituted a **proportionate** cutback on the grounds that "everybody should be treated alike"; therefore, they require each source to reduce emissions by 50 percent. Our two sources in Figure 12.3 both reduce emissions to 10 tons/month. At this point their marginal abatement costs would be different. Furthermore, we can calculate total abatement costs by remembering that total cost is the sum of marginal costs. Thus, for example, for Source A the total costs of 10 tons of emissions would be $\$(1.0 + 2.1 + \ldots + 16.5) = \$75.9$.

The following tabulation compares the compliance costs of the equiproportionate reduction and the effluent charge.

	Total Compliance Costs ($/month)	
	Equiproportionate Reduction	Effluent Charge
Source A	75.9	204.4
Source B	684.4	67.9
Total	760.3	272.3

Note how much the totals differ. The total compliance cost of an equiproportionate cutback is about 2.8 times the total cost of an emission charge. The simple reason is that the equiproportionate cutback violates the equimarginal principle; it requires the same proportionate cutback regardless of the height and shape of a firm's marginal abatement costs. The difference in total costs between these two approaches is quite large with these illustrative numbers. We will see in later chapters that in the real world of pollution control these differences are often much larger. The extra amount spent to treat all firms with the same proportionate percentage could have been used to further reduce pollution.

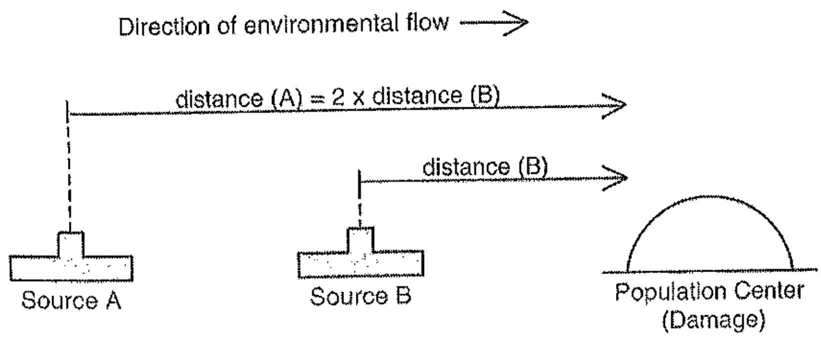
The higher the tax rate, the more emissions will be reduced. In fact, if the tax rate were increased to something over $55/ton, Firm A would stop emitting this residual entirely. The marginal abatement cost function for Firm B increases so rapidly, however, that an extremely high charge (more than $1,187/ton) would be required to get this source to reduce emissions to zero. A single effluent charge, when applied to several firms, will induce a greater reduction by firms whose marginal abatement costs increase less rapidly with emission reductions than from firms whose marginal abatement costs increase more rapidly. Because the firms are paying the same tax rate, they will have different total abatement costs and different tax bills. In Figure 12.3 the total abatement costs are equal to area *b* for Source A and area *d* for Source B. On the other hand, the monthly tax bill sent to Source A would be only *a*, compared to a bill of *c* sent to Source B. Thus, the less steeply the marginal abatement cost of a firm increases, the larger that firm's emission reduction will be and the smaller its tax bill.

It needs to be emphasized that the efficiency results of the emission charge approach (i.e., that it satisfies the equimarginal principle) are achievable *even though the administering agency knows nothing about the marginal abatement costs of any of the sources.* This is in clear contrast with the standards approach, where the public agency has to know exactly what these marginal abatement costs are for each firm in order to have a fully efficient program. In a charge approach the only requirement is that firms pay the same tax and that they are cost minimizers. After each one has adjusted its emissions in accordance with its marginal abatement costs (which we can expect them to know themselves), they will all be emitting at the appropriate rates to satisfy the equimarginal principle.

Emission Taxes and Nonuniform Emissions

So far the discussion has proceeded under the assumption that the emissions of all sources are uniformly mixed together; that is, the emissions from one source have the same marginal impact on ambient quality levels as those from other sources. In the real world this is usually not the case. Very often the situation is something like, although of course more complicated than, that depicted in Figure 12.4. Here there are two sources. Source A, however, is about twice as far away from the center of population as Source B. This means that emissions from Source A do not produce as much damage in the urban area as emissions from Source B. If the two sources are emitting some material into a river that flows toward the city, the emissions of Source A have a longer time in the water to be broken down and rendered less harmful than do the emissions from Source B. Or if it is an air-pollution problem, Source A is much farther upwind than Source B, so there is more time for its emissions to be spread out and diluted than there is for the emissions from Source B. There could be other reasons

FIGURE 12.4 Nonuniform Emissions



than location differences for the different impacts; for example, they may emit residuals at different times of the year when wind patterns are different. Studying the location problem will allow us to examine the general problem of nonuniform emissions.

In this case a single emission charge applied to both sources would not be fully efficient. A single charge addresses only the problem of differences in marginal abatement costs, not differences in damages caused by the emissions from different sources. In Figure 12.4, a one-unit reduction in emissions from Plant B would improve environmental quality (reduce damages) in the urban area more than a one-unit reduction in emissions from Plant A, and this fact must be taken into account in setting emission charge rates. Suppose emission reductions at Source B are twice as effective at reducing damages as reductions in emissions at Source A. This means, in effect, that the effluent tax paid by Source B must be twice as high as the effluent charge paid by Source A.[2] Thus, after adjustment to these tax levels the marginal abatement cost of Source B would be twice the marginal abatement cost of Source A. But the damage reduction *per dollar spent in reducing emissions* would be equalized across the two sources.

The logic of the preceding discussion would seem to imply the conclusion that in these cases we would have to charge different emission charges to each source. To do this we would have to know the relative importance of the emissions from each source in affecting ambient quality. Exhibit 12.2 discusses some recent results showing that for several important air pollutants, damages were substantially different among sources. The best response here might be to institute what is called a **zoned emission charge.** Here the administering agency would divide a territory into separate zones; the actual number of zones would depend on the circumstances of the case. Within each zone the agency would charge the same emission charge to all sources, whereas it would charge different charges in different zones.

Naturally the zones would be identified by grouping together sources whose emissions have similar effects on ambient quality levels. Figure 12.5, for example, shows the schematic of a river with a dozen different sources of emissions and one urban area where water quality is measured and water quality targets are established. The 10 upstream sources are strung along the river at increasing distances from the urban area. Thus, each has a different impact on measured water quality at the monitoring station, and a fully cost-effective program of emissions reductions would have to account for this fact *in addition to* their different marginal abatement costs. But it would be administratively very

[2] The technical concept here is called a "transfer coefficient." A transfer coefficient is a number that tells how the emissions from any particular source affect ambient quality at some other point. In the previous example, suppose 1 ton of SO_2 emitted by B would increase SO_2 concentration over the urban area by 0.1 ppm. Then a ton emitted from Source A would increase the ambient concentration by 0.05 (assuming an effect that is strictly proportional to distance). If the transfer coefficient for Source B is 1, that for Source A is 0.5, so the tax at A has to be half the tax at B. More generally, if the transfer coefficient at A is t_1, and that of B is t_2, then the tax at A should be t_1/t_2 times the tax at B.

Emissions from Different Sources Can Produce Very Different Damages

EXHIBIT 12.2

Different sources with the same type and quantity of emissions may be very different in terms of the damages they cause. Two economists recently estimated source-specific damages from emissions of major pollutants from power plants in the United States. They used a large-scale model that tracks the consequences of emission through air quality changes, exposure levels, dose-response information, and the valuation of resulting health impacts on affected populations. Some results are shown in the following table. Results are in the form of "trading ratios," which is the number of tons of pollutant emitted from the power-plant stack that causes the same amount of damage as would 1 ton emitted at ground level at the same site. The results shown are for fine particulate matter ($PM_{2.5}$) and sulfur dioxide (SO_2). The top four power plants are near urban areas and the bottom four are in rural locations.

For the urban power plants, note the differences for the Con Edison plant in New York: it would take 11 tons of $PM_{2.5}$ emitted from the stack to produce the same damage as 1 ton emitted at ground level. For SO_2 it would take 8 tons coming out of the stack to generate the same damages as 1 ground-level ton. For the rural plants the results are very different; here the stack and ground-level emissions produce the same levels of damage.

What these results show is that there can be very substantial differences between sources in terms of damages produced by the same pollutant.

Ground Source (city, state)	Power Plant (firm, facility)	Stack Height (feet)	Trading Ratios $PM_{2.5}$	Trading Ratios SO_2
New York, NY	Con Edison, 74th Street station	495	11:1	8:1
Washington, D.C.	Potomac Power Resources	400	23:1	8:1
Atlanta, GA	Georgia Power Co.	835	19:1	5:1
Houston, TX	Texas Genco, Inc. W.A. Parish	600	17:1	10:1
Grant Country, WV	Dominion, Mount Storm Station	740	1:1	1:1
Rosebud County, MT	PPL Montana, Colstrip Steam Elec	690	1:1	1:1

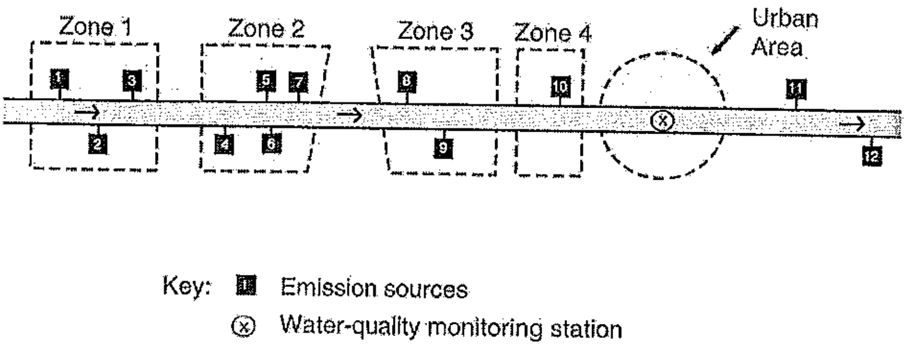
The trading ratio is the number of tons emitted from the stack of a power plant that would cause the same damage as 1 ton from a ground source at the same site.

Source: Nicholas A. Muller and Robert Mendelsohn, "Efficient Pollution Regulation: Getting the Prices Right," *American Economic Review*, 99(5), 2009, pp. 1714–1739.

costly to apply a different emissions charge to each source. We might, in this case, fall back on a zoned emission charge.

We first define different zones along the river, then apply the same tax to all sources within the same zone, but different taxes to sources in different zones. Each zone would contain sources whose emissions have roughly the same impact on measured water quality. In Figure 12.5, for example, four upstream

FIGURE 12.5 Zoned Emissions Charge



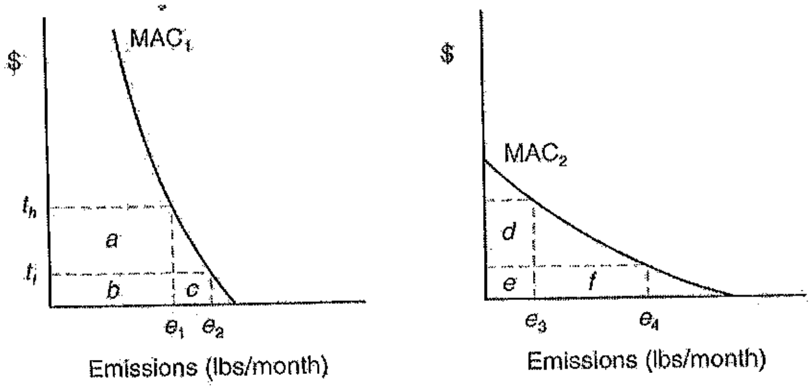
zones along the river are sketched out. The three sources in Zone 1 would pay the same charge, as would the four sources in Zone 2, and so on. Sources 11 and 12 are downstream from the urban area and may not get taxed at all. Of course, this is a simplified diagram to show the basic idea; in the real world, there would also very likely be downstream damages. By using a zone system, we can achieve a certain amount of administrative simplification while recognizing differences in the locations of different groups of sources.

Emissions Charges and Uncertainty

Pollution-control policies have to be carried out in a world of **uncertainty.** Administrative agencies often do not know exactly what emissions are being produced by each source or exactly what the human and ecosystem impacts are. Another source of uncertainty is the shape of the marginal abatement cost curve of the sources subject to control; these may be known reasonably well by the polluters themselves, but administrators usually will be very unsure of how high they are, how steep they are, how much they differ from source to source, and so on. It is one of the advantages of emissions charges that they can bring about cost-effective results even within that state of uncertainty.

Nevertheless, when administrators set taxes at certain levels, they normally will be uncertain about how much emission reduction will ensue, for that depends on how sources respond to the tax. This is one of the drawbacks of emission charges. It may be difficult to predict accurately how much total emissions will decrease because exact knowledge of marginal abatement costs is often lacking. Observe Figure 12.6. It shows two different marginal abatement cost functions, a steep one (MAC_1) and one that is much less steep (MAC_2). Consider MAC_1. If the charge were set at the relatively high rate of t_h, this source would reduce emissions to e_1, whereas if it were set at the low rate of t_l, it would adjust emissions to e_2. These two emission rates are relatively close together. In other words, whether the charge is high or low, the emissions rate of this source would not vary much; we could count on having an emissions rate of something in the vicinity of e_1 and e_2.

FIGURE 12.6 Emission Charges, Uncertainty, and Tax Revenues



But for the firm with the less steep marginal abatement costs (MAC_2), things are much more unstable. If the charge were set low, it would change emissions to e_4, whereas with a high charge emissions would go all the way down to e_3. In other words, for given changes in the tax rate, this firm would respond with much larger changes in emission rates than would the source with the steeper MAC curve.

The upshot of this discussion is that if most firms in a particular pollution problem have relatively flat MAC functions, regulators may have trouble finding the charge rate that will give us just the amount of reduction in total emissions we want. Because they don't know exactly where the MAC functions really are, they don't know exactly how high to set the tax. If they set it a little high or a little low, these firms will respond with large changes in their emissions. This is one of the main reasons administrators opt for standards: they seem to offer a definite control on quantities of emissions produced. In the next chapter, we will discuss an incentive approach that addresses this problem.

Emission Charges and Tax Revenues

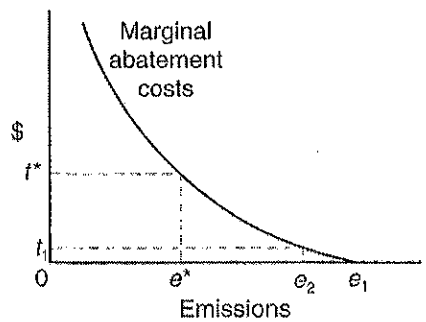
Another important aspect of emission charges is that they lead to **tax revenues** accruing to the government (see Example 12.1). Carrying this line of thought further has suggested to many people that society could benefit by replacing certain existing taxes with emission taxes. Many countries tax employment, for example. When firms hire workers, they must pay employment taxes to cover such things as the public costs of unemployment insurance and social security payments. But employment taxes lead to reduced levels of employment because, in effect, they make hiring workers more expensive. A government, therefore, might reduce its employment taxes and increase emission taxes in such a way as to keep its total tax revenue the same. This action has come to be known as the **double-dividend hypothesis**. This refers to the fact that society would gain both from the emissions taxes (through reduced emission damage) and from reduced employment tax (through increased employment).

Charges for Pollution Control Versus Charges for Raising Revenue

EXAMPLE 12.1

Because emission charges generate monetary tax receipts by government, they often have been thought of as a useful way of raising money to cover costs rather than as a way to motivate reductions in emissions. In recent years there has been some small movement toward emission charges in the United States. The Clean Air Act of 1990 requires states to use permit fees (in Chapter 14 we will study this program and the permit system it incorporates) to recover the administrative costs of running the permit program. Permit fees are simply the charges polluters have to pay in order to procure their operating permits from the environmental regulatory authorities. Some states have set permit fees that vary by quantity of emissions; thus, the fees effectively become emission charges. Maine, for example, has installed a three-part emission fee for sulfur oxides, NO_x, volatile organic compounds, and particulate matter. The current values are \$5.28 per ton for up to 1,000 tons per year, \$10.57 per ton for total annual emissions between 1,000 tons and 4,000 tons, and \$15.85 per ton for sources emitting more than 4,000 tons per year. New Mexico charges \$10 per ton for these types of pollutants, but \$150 per ton for emissions of toxic pollutants.

Emission permit charges like these, and similar ones for waterborne discharges in many states, may sound rather substantial, but probably are much more effective at raising revenues than at producing reductions in emissions. We are probably in a situation as depicted in the accompanying graphic.



The initial emission level is e_1, and the authorities set a maximum target of e^* for the firm. An emission tax rate of t^* would provide the incentive needed to bring about a reduction of emissions to e^*. But this would entail a substantial tax obligation for the firm. Instead, the authorities establish a charge at a rather low level, for example, t_1. This has very modest incentive effects; it leads the firm to reduce emissions from e_1 to e_2. But it provides a tax revenue to the regional agency equal to the cross-hatched area, which is enough to fund the public agencies that are running the program.

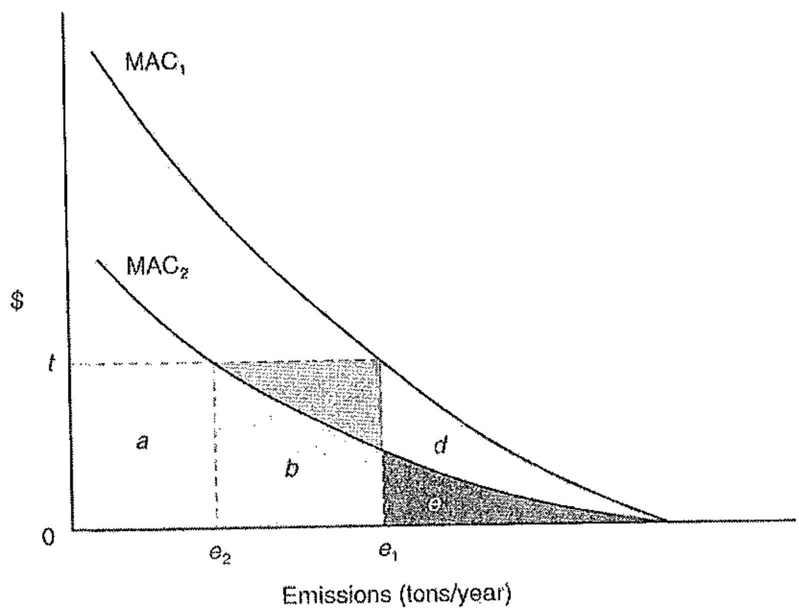
But predicting the revenue impacts of emission taxes may be difficult. Suppose, in Figure 12.6, an emission tax was increased from t_l to t_h. If the aggregate marginal abatement costs of the affected firm is MAC_1, total tax revenue will increase from $(b + c)$ to $(a + b)$. But if the marginal abatement cost is actually MAC_2, raising the emission tax will cause tax revenues to decrease from $(e + f)$ to $(d + e)$. This is because in the case of MAC_2 the tax increase leads to a large decrease in emissions, while in the case of MAC_1 it does not. Thus if the tax authorities don't know much about the shape and location of the relevant marginal abatement, they may be in for some major surprises in terms of changes in tax revenues.

Research on the double-dividend idea has also brought out another important factor. This is the potential impact of increased prices of the goods and services produced by the sectors subject to emission taxes. This can have a direct negative effect on the welfare of consumers of these goods and services. It can also have an indirect effect working through changes in the labor market.[3]

Emission Charges and the Incentives to Innovate

In a dynamic world, it is critical that environmental policies encourage technological change in pollution control. One of the main advantages of emission charges is that they provide strong incentives for this. This is shown in Figure 12.7, which shows two marginal abatement cost curves for a single firm. MAC_1 represents the current condition. It shows the costs the firm would experience in cutting back its emissions with the particular technology it currently uses. MAC_2, on the other hand, refers to abatement costs that the firm would experience after engaging in a relatively expensive research-and-development (R&D) program to develop a new method of reducing emissions. Assume the firm has a reasonably good idea of what the results of the R&D will be,

FIGURE 12.7 Emission Charges and the Incentive for R&D



[3] See Don Fullerton and Gilbert E. Metcalf, "Environmental Taxes and the Double-Dividend Hypothesis: Did You Really Expect Something for Nothing?" *Chicago-Kent Law Review*, 73(1), 1998, pp. 221–256.

although of course nothing is ever a sure thing. We can use it to measure the strength of the incentives for this firm to put money into the R&D program.

Suppose the firm is subject to an effluent charge of t/ton of emissions. Initially it will reduce emissions to e_1; at this point its total pollution-related costs will consist of $(d + e)$ worth of abatement costs and a tax bill of $(a + b + c)$. If it can lower its marginal abatement cost curve to MAC_2 through the R&D activities, it would then reduce its emissions to e_2. At this point it would pay $(b + e)$ in abatement costs and a in taxes. The reduction in total costs has been $(c + d)$. If the firm had instead been faced with an emissions standard of e_1, its cost savings with the new technology would have been only d, as we saw in the last chapter. Also, as we saw in the last chapter, if public authorities shift the standard to e_2 when the new technology becomes available (giving the same emissions reduction as the tax would have), the firm could actually experience an *increase* in costs because of its R&D efforts.

Thus, the firm's R&D efforts will lead to a bigger reduction in its pollution-control-related costs (abatement costs plus tax payments) under a policy of emission charges than under a standards approach. *Additionally, under the charge system the firm would automatically reduce its emissions as it found ways to shift its marginal abatement cost function downward, whereas under the standard no such automatic process would result.* The difference is that under a charge approach, polluters must pay for emissions as well as for abatement costs, whereas with standards they only need to pay abatement costs. So their potential cost savings from new pollution-control techniques are much larger under the charge program.

Emission Charges and Enforcement Costs

Charges pose a different type of **enforcement** problem than standards. Any charge system requires accurate information on the item to be taxed. If emissions are to be taxed, they must be measurable at reasonable cost. This means that residuals flowing from a source must be concentrated in a small enough number of identifiable streams that monitoring is possible. This rules out most nonpoint-source emissions because they are spread thinly over a wide area in a way that makes them impossible to measure. It would normally be impossible to tax the pollutants in city street runoff because the diffuse nature of the "emissions" makes them impossible to measure. This also may rule out certain toxic chemical emissions, which, in addition to being nonpoint source, often involve such small quantities that their flow rates are difficult to measure.

With emission charges the taxing authorities would be sending a tax bill to the polluting firms at the end of each month or year, based on their total quantity of emissions during that period. So the agency would require information on cumulative emissions from each source. This is more involved than just information on rate of discharge because cumulative discharge is rate times duration. There are several ways of getting this information. Perhaps the most ideal would be to have permanent monitoring equipment that measures emissions continuously over the time period in question. Lacking such technology, one could fall back on periodic checking of the rate of emissions, with an estimate of the duration based on normal business considerations or perhaps self-reporting by firms. Alternatively, engineering studies might be carried out to determine prospective emission quantities under specified conditions of operation, inputs used, and so on.

It is probably fair to say that the **monitoring requirements** of an emissions charge policy are more stringent than those for the typical standards program. Polluters, of course, have incentives to find ways, legal and otherwise, to get their tax bills reduced. One way to do this is to influence the monitoring process enough so that reported emissions are smaller. Once they do get their tax bills, recipients will have every incentive to contest them if they appear to be based on uncertain data or have other technical weaknesses. The lack of high-quality monitoring and reporting procedures has undoubtedly contributed to the unpopularity of effluent charge policies for environmental quality control.

Other Types of Charges

So far we have discussed only one type of charge, an effluent or emissions charge. Because it is the emission of residuals that leads directly to environmental pollution, charges on emissions presumably have the greatest leverage in terms of altering the incentives of polluters. But it is often impossible or impractical to levy charges directly on emissions. In cases where we can't measure and monitor emissions at reasonable cost, charges, if they are to be used, would obviously have to be applied to something else. A good case of this is the problem of water pollution from fertilizer runoff in agriculture. It is impossible to tax the pounds of nitrogen in the runoff because it is a nonpoint-source pollutant and thus not directly measurable. The same problem applies to agricultural pesticides. What may be feasible instead is to put charges on these materials as they are bought by farmers—that is, say, a charge per ton of fertilizer or per 100 pounds of pesticide purchased. The charge is to reflect the fact that a certain proportion of these materials ends up in nearby streams and lakes. Because they are paying higher prices for these items, farmers would have the incentive to use them in smaller quantities. Higher prices also create an incentive to use the fertilizer in ways that involve less wastage, for example, by reducing the amounts that run off.[4]

Placing a charge on something other than emissions is usually a "second-best" course of action made necessary because direct emissions can't be closely monitored. In cases such as this we have to watch out for distortions that can come about as people respond to the charge, distortions that can substantially alleviate the effects of the tax or can sometimes make related problems worse. We mentioned in Chapter 1 the move by many U.S. communities to tax household trash. One technique is to sell stickers to the residents and require that each bag of trash have a sticker on it. The rate of tax is determined by the price of the stickers, and it is relatively easy to monitor and enforce the system through the

[4] This is a case of taxing "goods" to control environmental "bads." See Gunnar S. Eskeland and Shantayanan Devarajan, "Taxing Bads by Taxing Goods: Pollution Control with Presumptive Charges," World Bank, 1996, http://www-wds.worldbank.

curbside pickup operations. But the per-bag tax will produce an incentive to pack more into each bag, so the reduction in total quantity of trash may be less than the reduction in the number of bags collected.

Distributional Impacts of Emission Charges

There are two primary impacts of effluent charges on the distribution of income and wealth:

1. Impacts on prices and output of goods and services affected by the charges, and
2. Effects from the expenditure of tax funds generated by the charges.

Businesses subject to a charge will experience an increase in costs because of both the abatement costs and the tax payments. From the firm's standpoint, these constitute increases in production cost, which the firm will presumably pass on to consumers just as with any cost of production. Whether and how much the firm can do this depends on competitive conditions and the conditions of demand. If the charge is applied to a single firm or small group of firms within a competitive industry, it will not be able to push its price up above the industry price, and so will have to absorb the cost increase. In this case the impacts will be felt entirely by owners of the firm and the people who work there. Many firms fear, or pretend to fear, being in precisely this situation and base their public objections to taxes on this outcome. If the charge is applied to an entire industry, prices will go up and consumers will bear part of the burden. How much prices go up depends on demand conditions.[5] Price increases often are thought of as regressive because, for any given item, an increase in its price would affect poor people proportionately more than higher-income people. For something that both poor and well-off people consume, such as electricity, this conclusion is straightforward. For price increases in goods consumed disproportionately by more well-to-do people (e.g., airline travel), however, the burden would be mostly on them.

The burden on workers is tied closely to what happens to the rate of output of the affected firms. Here again, the extent of the output effect depends on competitive conditions and the nature of the demand for the good. If the emission tax program is applied to a single firm in a competitive industry or if the demand for the output of an industry is very responsive to price, output adjustments will be relatively large and workers could be displaced. The long-run burden is then a matter of whether good alternative sources of employment are available.

Although burdens because of price and output changes may be real, we have to remember that, on the other side, the charge program is creating substantial benefits in the form of reduced environmental damages. To know how a program affects any particular group, we would have to account also for how these benefits are distributed.

[5] This was discussed in greater detail in Chapter 8.

Effluent charges also could involve substantial sums going from consumers of the goods produced by the taxed industry to the beneficiaries, whomever they may be, of the funds collected by the taxing authorities. These funds could be used for any number of purposes; how they are used would determine their impacts. They might, for example, be distributed to lower-income people to offset the effects of price increases. They even might be returned in part to the firms paying the effluent taxes. This is done in some European countries to help finance the purchase of pollution-control technology. As long as the return payments do not make the marginal emissions tax rate effectively lower, the incentive effects of the charge are not affected. Alternatively, they might be used to pay for other environmental initiatives in places where direct public action is called for. They even might be used to reduce overall budget deficits, with benefits flowing to general taxpayers.

Abatement Subsidies

An emission charge works by placing a price on the environmental asset into which emissions are occurring. Essentially the same incentive effects would result if, instead of a charge, we instituted a **subsidy** on emission reductions. Here a public authority would pay a polluter a certain amount per ton of emissions for every ton it reduced, starting from some benchmark level. The subsidy acts as a reward for reducing emissions. More formally, it acts as an **opportunity cost**; when a polluter chooses to emit a unit of effluent, it is in effect forgoing the subsidy payment it could have had if it had chosen to withhold that unit of effluent instead. Table 12.1, using the same numbers as in the preceding discussion on emission charges, shows how this works in principle. The firm's base level is set at its current emissions rate: 10 tons/month. It receives $120 per ton for every ton it cuts back from this base. The fourth column shows its total

TABLE 12.1 An Abatement Subsidy

Emissions (tons/month)	Marginal Abatement Cost	Total Abatement Cost	Total Subsidy at $120/Ton	Total Subsidy Minus Total Abatement Costs
10	0	0	0	0
9	15	15	120	105
8	30	45	240	195
7	50	95	360	265
6	70	165	480	315
5	95	260	600	340
4	120	375	720	345
3	150	525	840	315
2	185	710	960	250
1	230	940	1,080	140
0	290	1,230	1,200	−30

subsidy revenues, and the last column shows total subsidies minus total abatement costs. This net revenue peaks at 4 tons/month, the same emissions level the firm would choose with the $120 tax. In other words, the incentive for the firm is the same as for the tax.

Although an abatement subsidy like this would have the same incentive for each individual source, total emissions may actually increase. To understand why, note the difference in the financial position of this firm when it emits 4 tons of pollutant under the two programs: With the tax it has total costs of $855 (see Figure 12.1), whereas with the subsidy it has a total *revenue* of $345. Thus, the financial position of the firm is much different. In effect, it will be earning higher profits after the imposition of the subsidy, and this can have the effect of making this industry more attractive for potential new firms. There is the possibility, in other words, of having the emissions per firm go down but the number of firms in the industry increase, and therefore total emissions increase. This feature is a major drawback of simple subsidies like this.

Although subsidies linked directly to emission reductions have never become particularly popular, governments around the world have frequently resorted to many other types of subsidies to further the goals of pollution reduction. A few of these are listed in Exhibit 12.3.

Deposit-Refund Systems

One place where subsidies may be more practical is in deposit-refund systems. A deposit-refund system is essentially the combination of a tax and a subsidy. For example, a subsidy (the refund) is paid to consumers when they return an item to a designated collection point. The purpose of the subsidy is to provide the incentive for people to refrain from disposing of these items in environmentally damaging ways. The funds for paying the subsidy are raised by levying taxes (the deposit) on these items when they are purchased. In this case, the purpose of the tax is not necessarily so much to get people to reduce the consumption of the item, but to raise money to pay the subsidy. The tax is called a deposit and the subsidy a refund, but the principle is clear.

Deposit-refund systems are particularly well suited to situations where a product is widely dispersed when purchased and used, and where disposal is difficult or impossible for authorities to monitor. In the United States, a number of individual states[6] have enacted deposit-refund systems for beverage containers, both to reduce litter and to encourage recycling. This approach also has been widely used in Europe. But many other products could be handled effectively with this type of system.

In the late 1960s, Germany instituted a deposit-refund on waste lubricating oil. Each year very large quantities of waste oil are disposed of improperly, putting many air, water, and land resources under threat. In the German system, new lubricating oil is subject to a tax (a deposit), the proceeds of which go into a special fund. This fund is then used to subsidize (the refund side) a waste oil

[6] As of 2012 these were California, Connecticut, Hawaii, Iowa, Maine, Massachusetts, Michigan, New York, Oregon, and Vermont. Delaware repealed its law in 2010.

Types of Environmentally Related Subsidies

EXHIBIT 12.3

Subsidies in the Form of	Example(s)
Tax benefits	Tax exemptions for pollution-control equipment or recycling equipment Exemptions of ethanol-blended gas from federal taxes
Reduced environmental fines	Reductions in normal fines if firms undertake extensive pollution-control plans
Public grants to encourage environmental programs	EPA grants to communities to fund "brownfields" programs[1] Grants to farmers to adopt conservation practices Grants to businesses or communities to establish recycling programs
Development rights purchase programs	Public purchases of agricultural development rights to maintain land in agriculture or open space
Public support of environmental market development	Public rules on procurement of products made from recycled materials Cash payments for people who turn in old, high-emitting automobiles
Cost-sharing grants	Grants made to localities to cover a portion of the cost of building wastewater treatment facilities

[1]Brownfields are contaminated industrial sites that pose relatively low risks, but may be avoided by private developers because of potential liability problems.

recovery and reprocessing system. The terms of the subsidy are set so as to encourage competition in the recovery/reprocessing system and to provide an incentive for users to reduce the extent to which oil is contaminated during use.[7]

In Sweden and Norway, deposit-refund systems have been instituted for cars. New-car buyers pay a deposit at the time of purchase, which will be refunded when and if the car is turned over to an authorized junk dealer. Experience with these systems shows that success depends on more than just the size of the deposit-refund. For example, it is essential that the collection system be designed to be reasonably convenient for consumers.

[7] Peter Bohm, *Deposit-Refund Systems*, Baltimore, MD: Johns Hopkins Press for Resources for the Future, 1981, pp. 116–120.

Other items for which deposit-refund systems might be appropriate are consumer products containing hazardous substances, such as batteries containing cadmium, and car batteries.[8] Automobile tires also might be handled this way. The deposit-refund system also might be adaptable to conventional industrial pollutants. For example, users of fossil fuels might pay deposits on the quantities of sulfur contained in the fuels they purchase; they would then get refunds on the sulfur recovered from the exhaust gas. Thus, they would lose their deposit only on the sulfur that went up the stacks.

Summary

Emission charges attack the pollution problem at its source, by putting a price on something that has been free and, therefore, overused. The main advantage of emission charges is their efficiency aspects: if all sources are subject to the same charge, they will adjust their emission rates so that the equimarginal rule is satisfied. Administrators do not have to know the individual source marginal abatement cost functions for this to happen; it is enough that firms are faced with the charge and then left free to make their own adjustments. A second major advantage of emission charges is that they produce a strong incentive to innovate, to discover cheaper ways of reducing emissions.

The apparent indirect character of emission charges may tend to work against their acceptance by policymakers. Standards have the appearance of placing direct control on the thing that is at issue, namely, emissions. Emission charges, on the other hand, place no direct restrictions on emissions but rely on the self-interested behavior of firms to adjust their own emission rates in response to the tax. This may make some policymakers uneasy because firms apparently are still allowed to control their own emission rates. It may seem paradoxical that this "indirect" character of effluent taxes can sometimes provide a stronger inducement to emission reductions than seemingly more direct approaches.

But emission charges require effective monitoring. They cannot be enforced simply by checking to see if sources have installed certain types of pollution-control equipment. If emission charges are to have the appropriate incentive effects, they must be based closely on *cumulative emissions*. Thus, point sources where emissions can be effectively measured are the likely candidates for pollution control via emissions charges.

An advantage of emission charges is that they provide a source of revenue for public authorities. Many have recommended that tax systems be changed to rely less on taxes that have distorting economic effects and more on emissions charges. This requires that authorities be able to predict with accuracy the effects of particular emissions charges on rates of emissions.

Emissions subsidies would have the same incentive effect on individual polluters, but they could lead to increases in total emission levels. One place where subsidies have been used effectively is in deposit-refund systems, which are essentially tax and subsidy systems in combination.

[8] As of 2010, 13 U.S. states had deposit-refund systems for car batteries.

Questions for Further Discussion

1. How might an emission charge program be designed to address the problem of automobile emissions?
2. Explain how emission charges solve the equimarginal problem.
3. Opponents of emission charge policies sometimes assert that they are simply a way of letting firms buy the right to pollute. Is this a reasonable criticism?
4. When emission charges are put into effect, who ultimately ends up paying for them? Is this fair?
5. Emission charges are sometimes seen as creating a "double burden": Firms must pay the costs of reducing emissions and also pay the government for polluting discharges. How might a charge system be designed to reduce this double burden?

For additional readings and Web sites pertaining to the material in this chapter, see **www.mhhe.com/field6e**.