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NATURAL RESOURCE AND ENVIRONMENTAL ECONOMICS

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Natural Resource and Environmental Economics

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Table 6.3 The statistical value of a life as revealed by US EPA command and control regulations

Regulation	Initial annual risk	Expected annual lives saved	Cost per expected life saved ($US 1984)
Unvented space heaters	2.7 in 105	63.000	0.10
Airplane cabin fire protection	6.5 in 108	15.000	0.20
Auto passive restraints/belts	9.1 in 105	1850.000	0.30
Underground construction	1.6 in 103	8.100	0.30
Servicing wheel rims	1.4 in 105	2.300	0.50
Aircraft seat cushion flammability	1.6 in 107	37.000	0.60
Aircraft floor emergency lighting	2.2 in 108	5.000	0.70
Crane suspended personnel platform	1.8 in 103	5.000	1.20
Concrete and masonry construction	1.4 in 105	6.500	1.40
Benzene/fugitive emissions	2.1 in 105	0.310	2.80
Grain dust	2.1 in 104	4.000	5.30
Radionuclides/uranium mines	1.4 in 104	1.100	6.90
Benzene in workplace	8.8 in 104	3.800	17.10
Ethylene oxide in workplace	4.4 in 105	2.800	25.60
Arsenic/copper smelter	9.0 in 104	0.060	26.50
Uranium mill tailings, active	4.3 in 104	2.100	53.00
Asbestos in workplace	6.7 in 105	74.700	89.30
Arsenic/glass manufacturing	3.8 in 105	0.250	142.00
Radionuclides/DOE facilities	4.3 in 106	0.001	210.00
Benzene/ethylbenzenol styrene	2.0 in 106	0.006	483.00
Formaldehyde in workplace	6.8 in 107	0.010	72000.00

Source: Viscusi (1996), pp. 124–125

Box 6.3 Evolution in the USA from command and control towards incentive-based instruments for environmental regulation

A recent USA EPA report ('The United States Experience with Economic Incentives for Pollution Control'), available online at http://yosemite.epa.gov/ee/epa/eed.nsf/Webpages/USExperienceWithEconomicIncentives.html, noted two recent trends in the form of instruments used in the USA for environmental management. The first is an increasing diversity of economic incentives used by EPA. Historically EPA had relied on regulations to reduce pollution and improve the environment, but it has begun to use a wide variety of economic incentive mechanisms in recent years. Second, the number of applications of incentive-based instruments at other levels of government – at the state and local level – has grown rapidly.

The Report suggested several reasons for these trends:

- Incentives are proving to be particularly useful in controlling pollution that has not already been subjected to traditional forms of regulation. For example, volume-based disposal charges encourage households to reduce solid waste by recycling, composting and other means.
- Incentive-based instruments can sometimes be applied where traditional regulations might not be possible. They are particularly useful for small and geographically dispersed sources.
- Incentives generate benefits beyond what is possible with traditional regulations. Two benefits stand out. First, they provide cost savings relative to command and control (CAC). One study estimates potential savings of widespread use of economic incentives could reach $45 billion annually. On a practical level, acid rain trading savings are at least $700 million annually. Second, incentives can provide impetus for technological change.

The United States system of environmental controls is one of the most comprehensive to be found. A set of Congressional statutes provides the legal framework for the regulatory system, and give responsibility to the United States Environmental Protection Agency (US EPA) for implementing and administering the system. A comprehensive, and well-indexed, account of US environmental policy can be found on the 'Laws

Box 6.3 *continued*

& regulations' section of the US EPA website, http://www.epa.gov/lawsregs/. Here we focus on a number of important areas within that regulatory framework: air and water pollution, hazardous waste disposal, agricultural chemicals, toxic substances, and species protection. What is evident is that a framework initially based around conventional command and control regulations is increasingly characterised by the use of incentive-based instruments.

Air quality

The *Clean Air Act* defines ambient air quality standards for all parts of the USA for two types of pollutant: criteria (common) and hazardous air pollutants. *Criteria* air pollutants consist of particulates, SO_2, CO, NO_2, low-level ozone and lead. Each of these is given a *primary NAAQS* (National Ambient Air Quality Standard), set to protect human health. Some are also given a *secondary* NAAQS to protect wildlife, visibility and ecological systems. The levels of NAAQS for the criteria pollutants were listed in Table 5.4 in Chapter 5.

The system for *criteria* air pollutants is as follows. For *stationary sources* of air pollutants, the principal control instrument has been technology-based regulation, supported by maximum allowable emissions rates in some cases. *Existing pollution sources* must satisfy 'reasonably available control technology' (RACT). *New pollution sources* must meet more restrictive 'new source performance standards' (NSPS), based on the criterion of commercially available 'best technological system of emissions reduction'. Where NAAQS have not been met, stricter criteria may be used, such as 'lowest achievable emissions rate' (LAER), or in Class 1 (unspoilt) areas 'best available control technology' (BACT). Firms may be required to use particular techniques to recover fumes or waste products, or they may be prohibited from using certain production processes. Not surprisingly, the interpretation of these different criteria and the particular requirements that US EPA mandates for firms are contentious, and lead to significant amounts of judicial action.

For *mobile source* air pollution, control is largely directed at vehicle manufacturers, again in the form of required technology controls. Stricter controls are used in some non-attainment areas (such as mandated use of low-polluting fuels).

Although air pollution is mainly controlled by technology-based regulation, there are some exceptions. A flexible incentive-based system has been developed for acid-rain-inducing pollutants. Some states are experimenting with various market-based controls, such as those being used in the Los Angeles basin area.

In the cases of *hazardous air pollutants* (about 200 air toxins listed by US EPA), 'large' stationary sources must use 'maximum achievable control technology' (MACT). With the passage of time, US EPA has gone some way along the process of defining acceptable risk in operational terms.

The Acid Rain Program represents a dramatic departure from traditional command and control regulatory methods that establish specific, inflexible emissions limitations with which all affected sources must comply. Instead, the Acid Rain Program introduces an allowance-trading system that harnesses the incentives of the free market to reduce pollution:

- trading of sulfur dioxide allowances in the Acid Rain program, which encourages utilities to find least cost compliance strategies;
- basing air emission permit fees on the quantity of emissions.

Clean water

Water standards are again typically based on technology controls. In the initial control phase, this required the use of 'best *practical* technology' (BPT). Later control phases mandated the more stringent 'best *available* technology' (BAT). In addition to BAT, dischargers must acquire (non-marketable) effluent emissions licences, often containing very detailed plans about how discharges are treated as well as the amounts that may be discharged. Technology controls ('best-management practices') are also employed to reduce runoff from non-point sources (industrial and agricultural sites).

- Charging for the disposal of industrial effluents in water treatment plants.

Hazardous waste disposal

Under the terms of the Resource Conservation and Recovery Act, the US EPA has developed a list of about 450 hazardous substances. Disposal

Box 6.3 ***continued***

is controlled through location restrictions, required staff training, groundwater monitoring by disposing firms, and the requirement to construct detailed plans for site closure and post-closure practice. Operators must also undertake sufficient insurance cover. These, and other, restrictions are supported by a licence system. The Superfund has provided a mechanism for dealing with abandoned waste dumps. The fund is built up from general taxation and from taxes on the petroleum and chemical industries. The principle of 'strict, joint and several liability' establishes strong incentives throughout the waste cycle to minimise the amount of waste produced.

Toxic substances

The TSCA requires US EPA to review all new chemicals, and gives it authority to restrict use of, or ban, existing chemicals. Unlike most areas of environmental regulation, the TSCA requires balancing of the costs of regulation (in money terms) and the benefits of regulation (in terms of cancer or other serious health impacts avoided).

- Encouraging reductions in toxic emissions by broadly disseminating information about emissions through hazard warning labeling and in communities through the annual Toxics Release Inventory.

Agricultural chemicals

FIFRA imposes a duty of registration of all new pesticides. New ingredients in agricultural chemicals cannot be introduced until the US EPA is satisfied, after cost–benefit analysis, that the product will generate positive net benefits. EPA may also carry out Special Reviews on existing pesticides. As with TSCA, FIFRA requires that the EPA 'balance' benefits against costs in arriving at its decisions about bans or other restrictions. A study by Van Houtven and Cropper (1996) investigated 245 food crop applications of 19 pesticide active ingredients. Of these, 96 applications were banned after US EPA Special Reviews.

Examples of economic incentives discussed in the report include:

- subsidising farmers and others to conserve habitat and control pollution;
- requiring a deposit on beverage containers to encourage recycling, which now occurs in ten states; many states have a similar system for lead acid batteries;
- imposing liability for natural resource damages caused by oil and hazardous material spills, a incentive to encourage pollution prevention;
- promoting voluntary programs such as Energy Star, Waste Wise, XL and other programs that reduce pollution by assisting and rewarding voluntary actions to reduce energy use and limit pollution.

6.4 Economic incentive (quasi-market) instruments

Command and control instruments operate by imposing *mandatory* obligations or restrictions on the behaviour of firms and individuals. In contrast, incentive-based instruments work by altering the structure of pay-offs that agents face, thereby creating incentives for individuals or firms to *voluntarily* change their behaviour. The pay-off structures are altered by changing relative prices. This can be done in many ways.[12] We focus on two of them in this section:

1. by the imposition of taxes on polluting emissions (or on outputs or activities deemed to be environmentally harmful), or by the payment of subsidies for emissions abatement (or reduction of outputs or activities deemed to be environmentally harmful);

[12] The forms of incentive-based instruments that we focus on in this section are taxes (or other charges) on emissions, emissions abatement subsidies, and marketable emissions permits. But it follows that any instrument that manipulates the price system in such a way as to alter relative prices could also be regarded as an incentive-based instrument. Other forms, some of which are considered in this chapter or elsewhere in the book, include deposit-refund systems, liability payments, non-compliance fees, charges on landfill or other disposal of waste, and performance bonds.

2. by the use of tradable emission permit (or allowance) systems. Companies, or other controlled parties, are entitled to emit designated pollutants up to the quantity of allowance that they hold. Those allowances – summing in total to whatever aggregate target the EPA seeks to achieve – are distributed without charge to potential pollution emitters or are sold by auction. Given that allowances are tradable, permit markets will emerge with associated market prices. Those prices are, in effect, the cost of emitting pollutants.

Whichever of these two ways is chosen, prices exist which generate opportunity costs that profit-maximising firms or utility maximising individuals will take account of and so the instrument generates incentives to make behaviour less polluting.[13] We now examine these two approaches, looking first at the use of tax and subsidy instruments.

6.4.1 Emissions taxes and pollution abatement subsidies

In this section, we examine a tax on emissions, or a subsidy on emissions abatement. For simplicity, we begin with the special case of uniformly mixed pollutants, for which the magnitude of damage created by an emission is independent of the location of its source. It is shown later that the results also apply, with minor amendment, to non-uniformly-mixing pollutants. Given that taxes on emissions are equivalent to subsidies (negative taxes) on emissions abatement, it will be convenient to deal explicitly with tax instruments, and refer to subsidy schemes only when there is a difference that matters.

Looking again at Figure 6.4, it is evident that there are several points at which a tax could be applied (just as there were several points of intervention for command and control regulations).[14] We focus here on emissions taxes. It is important to note that taxes on output of the final product will not have the same effect as emissions taxes, and will generally be less efficient in attaining pollution targets. This matter is examined in Appendix 6.1 and in Problem 9 at the end of the chapter.

A tax on pollutant emissions has for long been the instrument advocated by economists to achieve a pollution target. It is useful to distinguish between three cases:

1. the pollution target is the economically efficient level of pollution (the level which maximises social net benefits);
2. a specific target is sought, but it is set according to some criterion other than economic efficiency;
3. the EPA has insufficient information to know how much emissions reduction will be obtained from any particular tax rate, but seeks an emission reduction of some unknown amount by arbitrarily selecting some emission tax rate.

We deal with each of these cases in turn. To attain the *efficient level* of pollution, it is necessary to have solved the net benefit maximisation problem discussed in the previous chapter. A shadow price for emissions implicitly emerges from that exercise, this price being equal to the monetary value of marginal damage from emissions at the socially efficient level of pollution. This is the rate at which the tax (or subsidy) should be applied per unit of emissions.

Figure 6.5 illustrates the working of an emissions tax. Note that the diagram uses aggregate, economy-wide marginal benefit and marginal damage functions (not those of individual firms). In the absence of an emissions tax, if firms behave without regard to the pollution they generate, emissions will be produced to the point where the private marginal benefit of emissions is zero. This is shown as $\hat{M}$, the pre-tax level of emissions.

Now suppose an emissions tax was introduced at the constant rate μ^* per unit emission, the value of

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[13] Liability can also be viewed as an incentive-based instrument, although we do not pursue that interpretation any further here.

[14] In fact, taxes could be levied even 'earlier' in the supply chain than indicated by the categories shown in Figure 6.4. Thinking about carbon dioxide emissions, for example, instead of levying taxes on CO_2 emissions at the production stage (where emissions are directly emitted) one could instead apply a tax on fossil fuel extracted at the resource extraction stage, where the tax rate is chosen to reflect the social cost of CO_2 emissions. A tax at this stage would cascade through the economy, changing the patterns of relative prices. This approach is examined in Chapter 8.

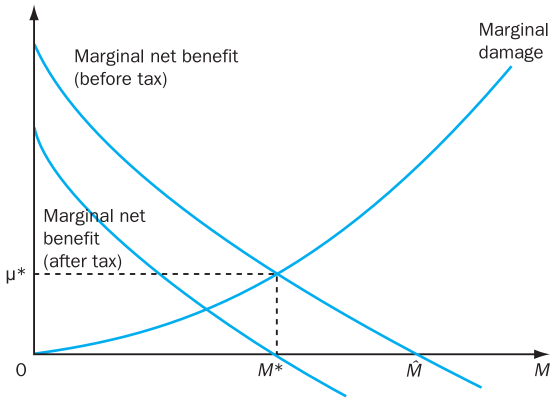

Figure 6.5 An economically efficient emissions tax

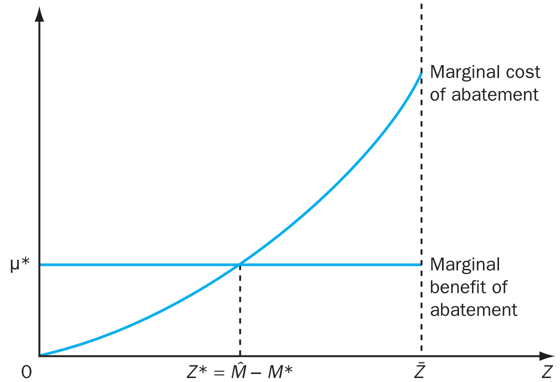

Figure 6.6 The economically efficient level of emissions abatement

marginal damage at the socially efficient pollution level. Given this, the post-tax marginal net benefit schedule differs from its pre-tax counterpart by that value of marginal damage. Once the tax is operative, profit-maximising behaviour by firms leads to a pollution choice of M^* (where the post-tax marginal net benefits of additional pollution are zero) rather than $\hat{M}$ as was the case before the tax. Note that levying an emissions tax at the rate μ^* creates just the right amount of incentive to bring about the targeted efficient emission level, M^*.[15]

It is sometimes more convenient to view the problem in terms of emissions abatement, Z, rather than the level of emissions, M. This can be done by reinterpreting Figure 6.5. Viewed in this new light, the emission tax causes abatement to increase from zero (at $\hat{M}$) to its efficient level $Z^* = \hat{M} - M^*$ at the point M^* on the horizontal axis of Figure 6.5. Alternatively, we can map the relevant parts of Figure 6.5 into abatement space, from which we obtain Figure 6.6.

It is important to be clear about the relationships between these two diagrams. First, the curve labelled 'marginal cost of abatement' in Figure 6.6 is just the mirror image of the (before-tax) marginal net benefit curve in Figure 6.5; what firms privately forgo when they abate emissions is, of course, identical to the benefits they receive from emissions. The 'marginal benefit of abatement' to a representative firm is the tax rate applied, μ^*. Each unit of abated emissions reduces the firm's total tax bill by that amount. As the tax rate is constant, the marginal benefit of abatement curve is horizontal. Secondly, note that we have truncated the two curves in Figure 6.6 at $Z = \bar{Z}$, where $\bar{Z}$ is identical in magnitude to $\hat{M}$. (You should confirm for yourself the reason for doing this.) Finally, note that $Z^* = \hat{M} - M^*$, and so the distance from the origin to Z^* in Figure 6.6 is equal to the horizontal distance between $\hat{M}$ and M^* along the emissions axis in Figure 6.5.

In the absence of an emissions tax (or an abatement subsidy), firms have no economic incentive to abate pollution. (In terms of Figure 6.6, the marginal benefit of abatement lies at zero along the Z axis.) Profit-maximising behaviour implies that firms would then undertake zero abatement, corresponding to emissions $\hat{M}$. However, when an emissions tax is levied (or, equivalently, when an abatement subsidy is available) an incentive to abate exists in the form of tax avoided (or subsidy gained). It will be profitable for firms to reduce pollution as long as their marginal abatement costs are less than the value of the tax rate per unit of pollution (or less than the subsidy per unit of emission abated). If the tax/subsidy is levied at the level μ^* the efficient pollution level is attained without coercion, purely

[15] As shown in Appendix 6.1, a subsidy at the rate μ^* on units of pollution abated would have an equal short-run effect on emissions to a pollution tax at the rate μ^* on unabated units of pollution.

as a result of the altered structure of incentives facing firms.

In the language of externalities theory, the tax eliminates the wedge (created by pollution damage) between private and socially efficient prices; the tax brings private prices of emissions (zero, before the introduction of the tax) into line with social prices (μ^*). The tax 'internalises the externality' by inducing the pollution generator to behave as if pollution costs entered its private cost functions. Decisions will then reflect all relevant costs, rather than just the producer's private costs, and so the profit-maximising pollution level will coincide with the socially efficient level.

Not only will the tax instrument (at rate μ^*) bring about a socially efficient *aggregate* level of pollution but it will also achieve that aggregate target in a cost-effective way. Remember that cost-efficiency requires that the marginal abatement cost be equal over all abaters. Under the tax regime all firms adjust their firm-specific abatement levels to equate their marginal abatement cost with the tax rate. But as the tax rate is identical for all firms, so are their marginal costs.

This is a remarkable result. Knowledge of both the aggregate marginal pollution damage function and the aggregate emissions abatement cost function are necessary for achieving a socially efficient emissions target at least real resource cost to the economy as a whole. But it is ***not*** necessary to know *each firm's* marginal abatement cost function. Compare this result with the case of command and control instruments where attaining an aggregate target at least real resource cost *does* need that additional, and far more demanding, information set: each firm's marginal abatement cost function.

Our discussion in this section so far has dealt with the case in which the EPA wishes to attain the economically efficient level of emissions, M^*. However, the EPA may not have sufficient information for this to be feasible, or it may wish to set an overall emissions target on some other basis. Suppose that the EPA does have an emissions target, $\tilde{M}$, set perhaps on health grounds. In terms of diagrams, we now need a slightly different version to that shown in Figure 6.5. The most likely reason that the EPA does not have sufficient information to use an economically efficient target is that it does not know the location of the marginal damage function. Alternatively, if the EPA sets a target on some ground other than economic efficiency, the marginal damage function as shown in Figure 6.5 is being treated as irrelevant, and a target $\tilde{M}$ is being set exogenously. Figure 6.7 illustrates. Figure 6.7 has been drawn such that the exogenously set emissions target, $\tilde{M}$, is more strict than the efficient target in 6.5.

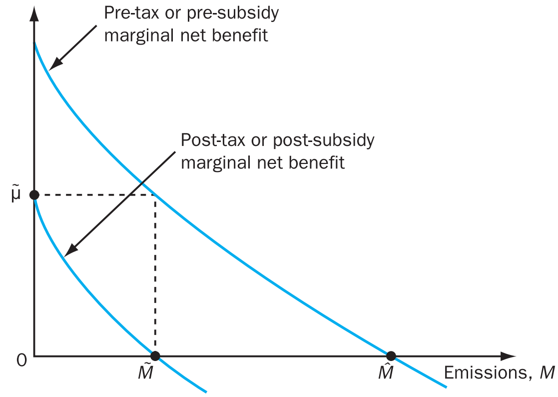

Figure 6.7 Emissions tax and abatement subsidy schemes when marginal damage is unknown, or when a target is being set on grounds other than economic efficiency

Figure 6.7 makes it clear that to attain this (or indeed any other specific) emissions target using a tax or subsidy instrument, knowledge of the aggregate (pre-tax or pre-subsidy) marginal benefit of emissions function would be sufficient. For any target $\tilde{M}$, the location of that function allows the EPA to identify the tax rate, say $\tilde{\mu}$, that would create the right incentive to bring about $\tilde{M}$. Note that as Figure 6.7 is drawn to show a target more strict than M^*, the shadow price of emissions (the implied tax rate or unit emission subsidy) $\tilde{\mu}$ is higher than μ^*.

By construction, the marginal net benefit of emissions function is exactly equivalent to the marginal abatement cost function. So the reasoning given in the previous paragraph could be reworded so that it applies to Figure 6.6. Thus, for any target $\tilde{M}$, knowledge of the aggregate marginal cost of abatement function allows the EPA to identify the tax rate, say $\tilde{\mu}$, that would create the right incentive to bring about that outcome.