AFRICAN ECONOMIC RESEARCH CONSORTIUM (AERC)

COLLABORATIVE MASTERS DEGREE PROGRAMME (CMAP) IN ECONOMICS FOR SUB-SAHARAN AFRICA

JOINT FACILITY FOR ELECTIVES

Teaching Module Materials

ECON 537 - Environmental Economics II

(Revised: August, 2020)

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Module 4.1. Framing the Environmental Problem: Pollution (4 hours)

Learning Outcomes

This Module addresses one of the major sources of environmental problem: pollution. After going through the module, the reader is expected to:

- ✓ identify the various categories of pollutants and the types of environmental problem associated with each
- ✓ understand how the policy response required to solve a pollution problem depends on the type of pollutant in view
- ✓ understand how economics defines the efficient level of pollution and how the efficient levels are derived for a flow and for stock pollutants
- ✓ have a good understanding of the depth of the pollution problem in Africa.

Outline

4.1 Categories of Pollutants and the Efficient level of Pollution

4.1.1 Introduction: The pollution problem

In our consideration of the interactions between the economic system and the environment, we saw that an environmental problem emerges when the rate of waste discharged into the environment exceeds its assimilative capacity (the case of pollution) and/or when a renewable resource is harvested beyond its regenerative capacity so that the ecosystem functions are affected negatively. We have examined in Module 3, the issues associated with the sustainable management of renewable resources. This Module provides a framework for conceptualizing environmental problems focusing mainly on pollution.

Pollution is not only a problem by itself, it impairs all the other estuarine functions of the environmental resource base (ERB). The damage caused by pollution can take many forms. At high enough exposures to certain pollutants, human health can be adversely impacted, possibly even leading to death. Other living organisms, such as trees or fish, can also be harmed by pollution. Inanimate objects, such as physical infrastructure like buildings and sculptures can also be affected (such as when acid rain causes sculptures to deteriorate or when particulates cause structures to discolor). This relationship between the amount of waste emitted into the environment, the absorptive capacity of the ERB and pollution damage is illustrated in Figure 4.1.

The amount of waste products emitted determines the load upon the environment. The damage done by this load depends on the absorptive capacity of the environment (its capacity to assimilate waste products). If emissions load exceeds the absorptive capacity, then the pollutant accumulates in the environment.

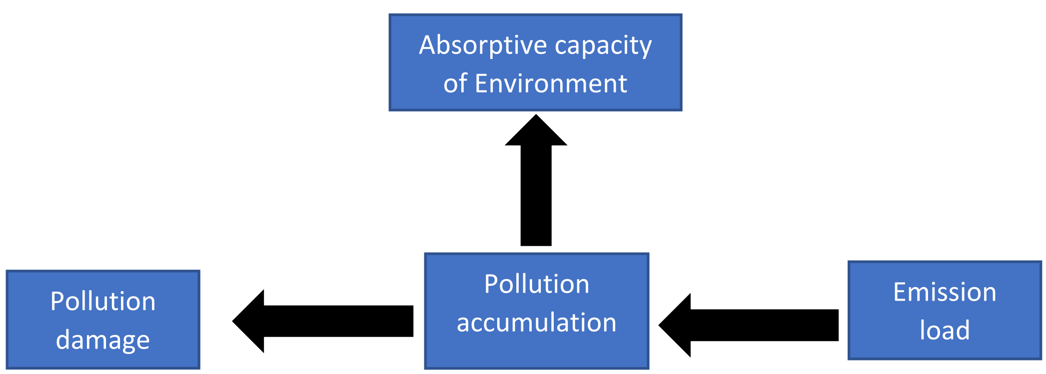

Fig. 4.1. Relationship between emissions and Pollution Damage. Source: Titenberg and Lewis, 2012.p360.

There are at least two questions that follow from the above.

- How much pollution abatement or control should society undertake? What is the appropriate level of pollution flow? How much pollution should society be willing to accept considering the benefits and costs of pollution control? and,
- How should the responsibility for pollution reduction be allocated among the various sources of pollution? Put differently, given that some target level of pollution has been chosen, what is the best method of achieving that level?

The second question has to do with pollution control policies and instruments. In that context, we will need a general framework for analyzing pollution control that allows us to define efficient and cost-effective allocations for a variety of pollutant types, compare these allocations to market allocations, and to demonstrate how efficiency and cost-effectiveness can be used to formulate desirable policy responses. This is the focus in Module 4.3. However, we need to first address the preceding questions.

4.1.2 What level of pollution is desirable?

From our consideration in Module 1, it is obvious that some level of waste discharge is required for the proper functioning of the ERB. In addition, it may not be possible to produce some goods and services that we do find useful and in the quantity in which they are needed without generating some pollution, even if only a small amount. To produce the goods and services we need in ways that are non-polluting may impose significant and unaffordable costs. The crucial question then is: what level of pollution should be considered desirable?

The answer to this question depends on what objective is being sought. If the objective is *economic optimality*, then the level of pollution chosen should be consistent with the maximization of social welfare. However, this criterion is not feasible in practice because the information required to establish the optimal pollution level is likely to be unobtainable[1]. In place of economic optimality, *economic efficiency* is often proposed as a more realistic goal for setting pollution targets. The use of efficiency criterion has aided the incorporation of natural resources into economic growth models. Pollution is then associated with resource extraction and use so that policies concerning pollution levels and natural resource uses are linked.

As we shall discover in Module 4.3, economic efficiency is not the only way of thinking about pollution targets. It may be necessary to adopt other considerations, such as sustainability, as the policy objective, or as a constraint that must be satisfied in pursuing other objectives. In this case, pollution levels (or their trajectories through time) would be assessed in terms of whether they

[1] This requires, among other things, knowledge of an appropriate social welfare function, and of production technologies and individual preferences throughout the whole economy and may also involve substantial redistributions of wealth.

are compatible with sustainable development. Efficiency and sustainability criteria do not usually lead to similar recommendations about pollution targets. However, pollution targets may be, and in practice often are, determined on grounds other than economic efficiency or sustainability. In some cases, policy may be based on what risk to health is deemed reasonable, or shaped by public opinion, or even pressure groups and sectional interests. In addition, political or political-economy considerations may in fact be hugely important in shaping the direction of policy goals. In addition, when the spatial influence of a pollution damage is transnational, policy makers may have to set targets within a network of obligations and pressures from various national governments and coalitions. In the final analysis, pollution targets are rarely, if ever, set entirely on purely economic grounds. Standards setting is usually a matter of trying to attain multiple objectives within a complex institutional environment. However, setting economic efficiency as the goal of pollution targets provides a useful framework for understanding environmental economics.

4.1.3. Efficient level of Pollution

What exactly constitutes an efficient allocation of pollution will depend on the nature of the pollutant and the associated damages. Different types of pollutants have different damage mechanism and hence differing impact on the absorptive capacity of the environment. They will therefore require different policy responses. Good public environmental policy requires an understanding of the nature of various pollutants, their effects on the environment, and their costs.

Pollution damages may arise from the flow of the pollutant (that is, the rate of emissions) or from the stock (or concentration rate) of pollution in the relevant environmental medium (see Figure 4. 2). **Flow-damage pollution** occurs when damage results only from the flow of waste discharge (the rate at which they are being discharged into the environmental system). This corresponds to the righthand side branch in Figure 4. 2. In this case, the damage will instantaneously drop to zero if the emissions flow becomes zero. This is exactly true when the pollutant exists in an energy form, such as noise or light, so that when the energy emission is terminated no residuals remain in existence. It may also be approximately true in a wider variety of cases, particularly when the residuals have very short lifespans before being transformed into benign forms.

The flow-damage pollution function can be represented as

$$D = D(M) \qquad (4.1)$$

Where M denotes the pollution flow, and D, pollution damage.

Stock-damage pollution: occurs when damage is a result of the stock of the pollutant in the relevant environmental system or environmental receptors (air, soils, biota and water systems) at any point in time. This corresponds to the central branch in Figure 4.2. For a stock of the pollutant to accumulate, it is necessary that the residuals have a positive lifespan and that emissions are being produced at a rate which exceeds the assimilative capacity of the environment. This can also happen in the case of waste discharges for which the ERB has zero assimilative capacity (e.g. some synthetic chemicals, such as polychlorinated biphenyls, PCBs DDT and dioxins, and a number of heavy metals, some rubbish that are not biodegradable, and strongly radioactive elements such as plutonium with extremely long radiation half-lives.). In this case, the left-hand branch in Figure 4.2 will not exist.

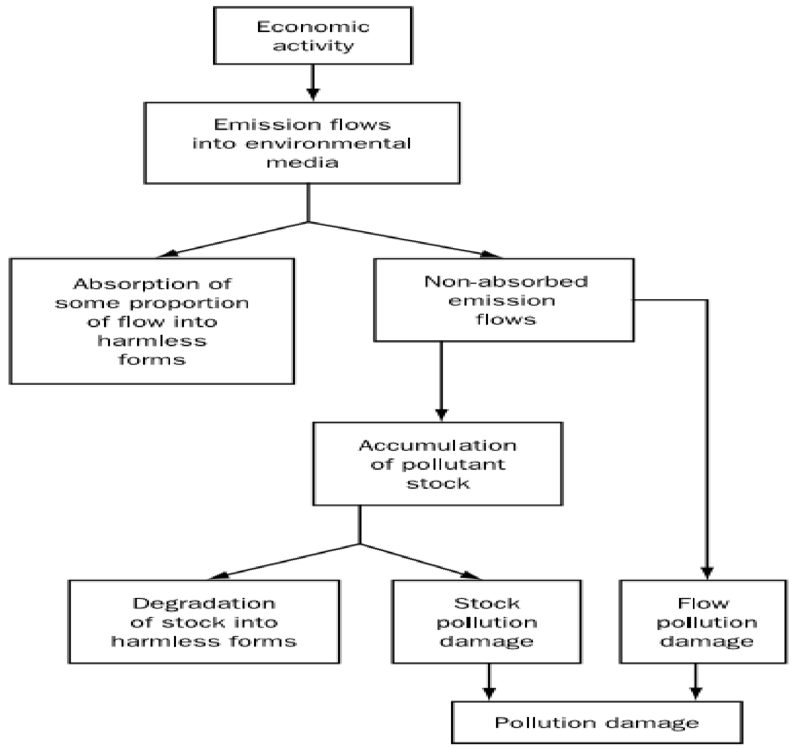

Fig. 4.2 Economic activity, residual flows and environmental damage.
Source: Perman et al., 2003. p.199.

Stock-damage pollution can be expressed in the equation below

$$D = D(A) \qquad (4.2)$$

where A is the pollution stock, and D, is the pollution damage.

There could be *mixed cases*, where pollution damage arises from both flow and stock effects. Examples considered in this category include waste emissions into water systems and damages arising from the emissions of compounds of carbon, sulphur and nitrogen.

Some authors prefer to classify pollutants themselves based on the above damage mechanisms. In this respect, we can distinguish between stock and fund pollutants. **Stock pollutants** are pollutants for which the environment has little or no absorptive capacity. Such pollutants accumulate over time as emissions enter the environment. **Fund pollutants** are pollutants for which the environment has some absorptive capacity. These pollutants will generally not accumulate as long as the emissions rate does not exceed the absorptive capacity of the environment.

It is also possible to classify pollutants by their *zone of influence*. This describe the geographic area affected by any given environmental or natural resources management problem. **Horizontal dimension of influence** refers to the spatial domain over which damage from an emitted pollutant is experienced (local, regional, global), while the **vertical zone of influence** shows whether pollution damage is caused mainly by ground-level concentrations of an air pollutant (as in the case of lead or particulates) or by concentrations in the upper atmosphere (as in the case of ozone-depleting substances or greenhouse gases, GHGs). The local and regional categories are also not mutually exclusive; it is possible for a pollutant to be both. Nitrogen oxides released into the air, for example, or chemical discharges into rivers can be both local and regional pollutants.

This taxonomy is very useful in designing policy responses to various types of pollution problems. Policies addressing the damage caused by local pollutants near the source of emissions, for example, will differ from those for regional pollutants affecting wider areas. In addition, many organic pollutants injected into an oxygen-rich stream will be transformed by the resident bacteria into less harmful inorganic matter. For example, emission of carbon dioxide is absorbed by plant life and the oceans. However, most important pollution problems have some attribute of a stock-damage pollution effect. The most prominent are those which affect human health and life expectancy. Others affect built structures, such as buildings, works of art etc. and may adversely affect production potential, particularly in agriculture. Stock pollution levels influence plant and timber growth, and the size of marine animal populations. Less direct effects operate through damages to environmental resources and ecological systems. They can also impair other functions of the ERB. Table 7.1 lists some atmospheric pollutants while Figure 7.3 illustrates the primary linkages between pressures, state and impacts of atmospheric change that are associated with some of them.

4.2 The Efficient Allocation of Pollution: Fund Pollutants vs. Stock Pollutant

4.2.1 The Efficient Allocation of Pollution: Fund Pollutants

To the extent that emission exceeds the assimilative capacity of the environment, fund pollutants accumulate in the atmosphere and share some of the characteristics of stock pollutants. When the emissions rate is low enough, however, the discharges can be assimilated by the environment, with the result that the link between present emissions and future damage may be broken. When this happens, current emissions cause current damage and future emissions cause future damage, but the level of future damage is independent of current emissions. This independence of allocations among time periods allows us to explore the efficient allocation of fund pollutants using the concept of static, rather than dynamic, efficiency.

Within this framework, we can identify two different types of costs: damage costs and control or avoidance costs. In particular, we need to know something about how control costs vary with the degree of (pollution) control and how damages vary with the amount of pollution emitted. It is generally agreed that marginal damage caused by a unit of pollution increases with the amount emitted (that is, the damage cost function is upward sloping in the level of emission) and that the marginal control costs increases with the amount of pollution control (put differently, the marginal control cost function is downward-sloping in the level of emission, or upward-sloping in the level of abatement).

Table 4.1: Some atmospheric chemical components

BC	**black carbon**
CFCs	chlorofluorocarbons
CH4	Methane
CO	carbon monoxide
CO2	carbon dioxide
GHGs	greenhouse gases
HCFCs	hydrochlorofluorocarbons
HFCs	hydrofluorocarbons
Hg	Mercury
N2 O	nitrous oxide
NH3	ammonia
NMVOC	non-methane volatile organic compounds
NO	nitrogen oxide
NO2	nitrogen dioxide
NOX	nitrogen oxides
O3	ozone, tropospheric and stratospheric
OC	organic carbon
ODS	ozone-depleting substances
PAHs	polycyclic aromatic hydrocarbons
Pb lead	PBDE polybrominated diphenyl ethers
PBTs	persistent, bioaccumulative, toxic chemicals (includes POPs, metals)
PCB	polychlorinated biphenyl
PFAS	per- and polyfluoroalkyl substances PM particulate matter
PM10	PM less than 10 µm in diameter
PM2.5	PM less than 2.5 µm in diameter
POPs	persistent organic pollutants (as defined by international agreements)
SO2	sulphur dioxide

Source: UN (2019), p.109

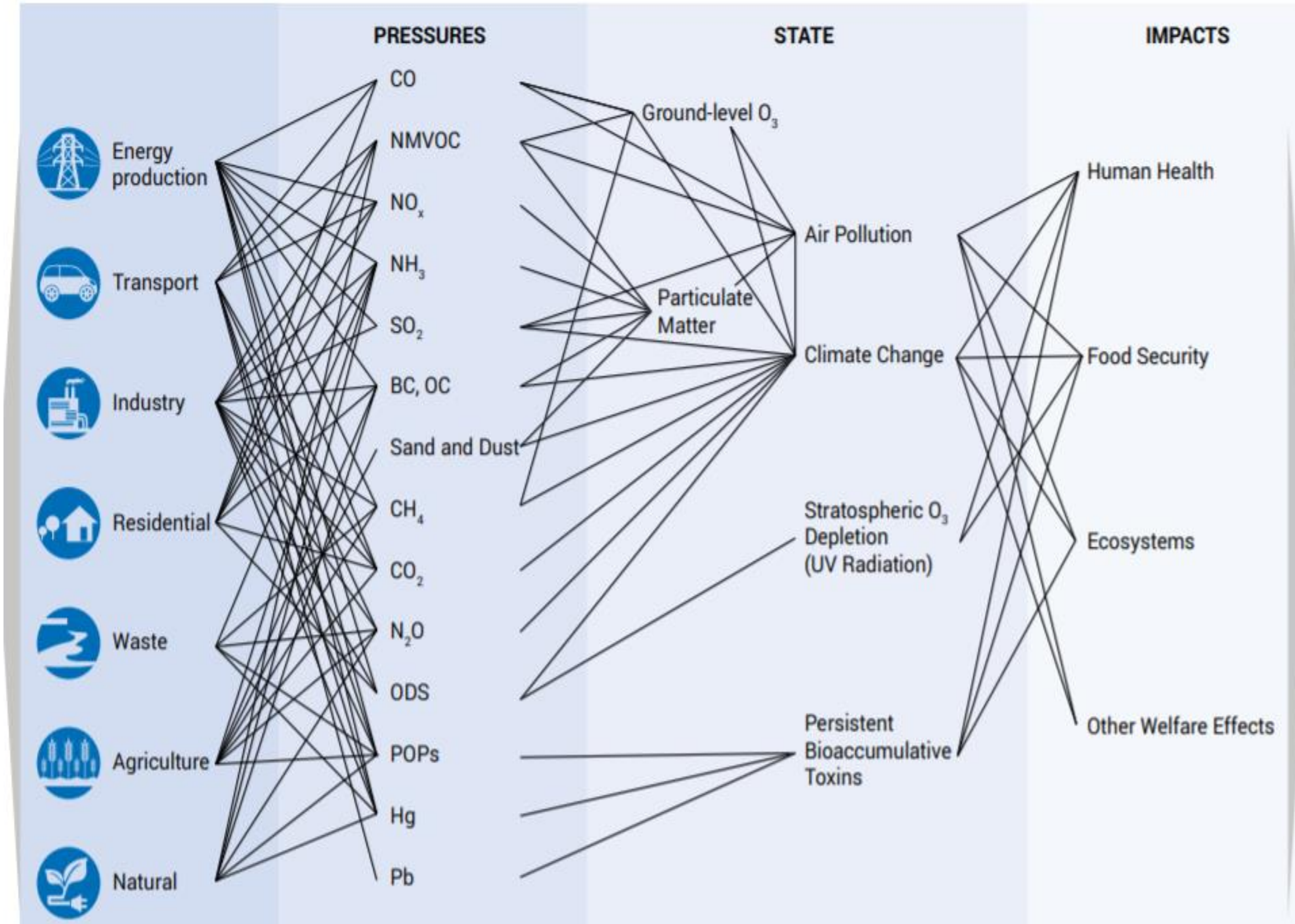

Fig. 4.3: Primary linkages between pressures, state and impacts of atmospheric change. **Source:** UN (2019), p.109

Intuitively, small amounts of pollution are easily diluted in the environment, and the body can tolerate small quantities of substances. However, as the amount in the atmosphere increases, dilution is less effective and the damage is more. Also, larger levels of pollution can lead to abrupt changes in ecosystems. An example is the present concern about climate change (Module 7.2). To understand the nature of the relationship between cost and pollution control, consider, for example, a firm that tries to reduce its particulate emission level by purchasing and installing electrostatic precipitator built to captures 80 percent of the particulates as they flow past in the stack. If it wants further reduction, it will have to install another precipitator and place it in the stack above the first one. But the additional precipitator will only capture 80 percent of the remaining 20 percent (or 16 percent of the uncontrolled emissions). Thus, the cost of additional unit of control increases as the level of control increases.

The efficient allocation for a fund pollution is at the point where the marginal damage cost is equal to the marginal control (abatement) cost (Figure 4.4). A movement from right to left on the horizontal axis refers to greater control and less pollution emitted. The marginal emission control cost can also be interpreted in terms of marginal benefit from pollution. Reducing emission control implies a reduction in control cost. This cost savings can be interpreted in terms of benefits from allowing more pollution. Thus, marginal abatement costs are equal to the marginal benefits that will be lost if emissions fall.

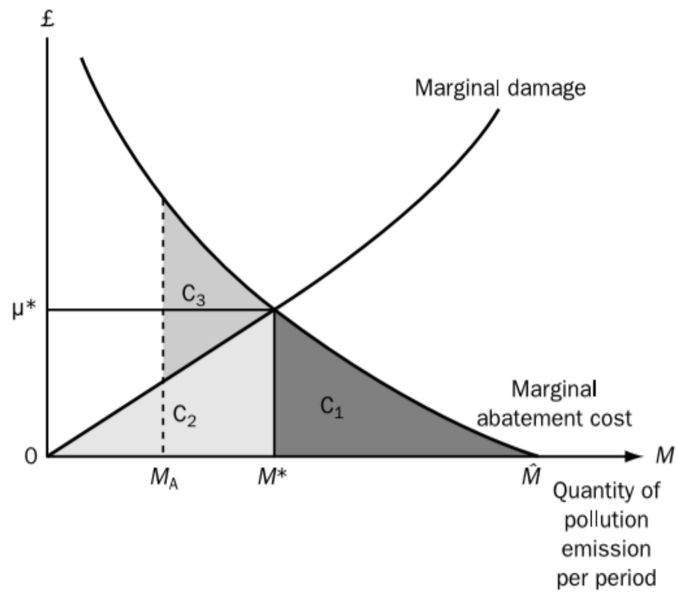

Fig. 4.4. Efficient allocation of a fund pollutant
Source: Perman et al.2003, p.173)

At the efficient allocation (M*), the damage caused by the marginal unit of pollution is exactly equal to the marginal cost of avoiding it. Put differently, the marginal benefit from pollution is equal to the marginal damage. The efficient level of pollution also minimizes the sum of total abatement costs plus total damage costs At M*, the sum of total damage costs (the area C_2) and total abatement costs (the area C_1) is C_2 + C_1.

Any other level of emissions will be inefficient because the further increase in avoidance costs would exceed the reduction in damages. For example, greater degrees of control or too little pollution (points to the left of M*, e.g., point M_A) implies a total cost of $C_1 + C_2 + C_3$, so that C_3 is the efficiency loss arising from the excessive abatement. Similarly, levels of control lower than M* (points to the right of M*) would result in a lower cost of control but the increase in damage costs would be even larger, yielding an increase in total cost.

The value of marginal damage and marginal benefit functions at their intersection is labelled μ* in Figure 4.4. We can think of this as the equilibrium 'price' of pollution. However, as there is no market for pollution, μ*is a hypothetical or shadow price rather than one which is actually revealed in market transactions. We could also describe μ* as the shadow price of the pollution externality. If a market were, somehow or other, to exist for the pollutant itself (thereby internalizing the externality) so that firms had to purchase rights to emit units of the pollutant, μ* would be the efficient market price.

As expected, the efficient level of pollution implies a positive amount of pollution. However, under certain conditions it is possible for the efficient level of pollution to be zero. In such cases, even a single unit of emission imposes a damage cost that exceeds the cost of control. This can be so for highly dangerous radioactive pollutants, such as plutonium, for example. This reality can be represented in Figure 4.4 by an upward shift of the damage cost curve of sufficient magnitude that its intersection with the vertical axis would lie above the point where the marginal cost curve intersects the vertical axis. In addition, the optimal level of pollution will generally not be the same for all parts of a country or region affected by the environmental pollution because of differences in ecological sensitivity, population concentration etc. For example, airports are mostly located outside cities or around the outer boundaries of cities.

In general, the optimal level of pollution will not be the same for all parts of a country (because of differences in ecological sensitivity). Areas that have higher population levels or are particularly sensitive to pollution would have a marginal damage cost curve that intersects the marginal control cost curve close to the vertical axis. Efficiency would imply lower levels of pollution for those areas. In contrast, areas that have lower population levels or are less sensitive should have higher efficient levels of pollution. For examples, some areas are less sensitive to acid rain than others because the local geological strata neutralize moderate amounts of the acid. Thus, the marginal damage caused by a unit of acid rain is lower in those regions than in other less tolerant regions. Also, pollutants affecting visibility are more damaging in national parks and other areas where visibility is an important part of the aesthetic experience than in other more industrial areas.

4.2.1.1 Modified efficiency targets

In some circumstances, society or policy makers may consider a particular effect or cost of pollution of primary importance, such as its effect on human health. In this case, pollution costs would be defined in terms of that effect alone. That leads to a revised or modified efficiency criterion in which the goal is to maximize the difference between all the benefits of pollution and this particular kind of pollution damage. Assume policy makers operate by making risks to human health the only damage that counts (in setting targets), how would this affect pollution targets? The answer depends on the relationship between emissions and health risks. One possible relationship is that illustrated by the vertical line in Figure 4.5a. It assumes strong discontinuity about human health risks associated with pollution. At levels of pollution below a threshold, M^H Total (and marginal) health damage is zero, but at M^H marginal damage becomes infinitely (intolerably) large. In this case, a modified efficiency criterion would require setting emissions target by the damage threshold alone.

It is also possible that marginal health damage is a rising and continuous function of emissions, as in Figure 4.5b. In this case, a trade-off exists in which lower health risks can be obtained at the cost of some loss of pollution benefits. With such a trade-off, both benefits and costs matter and a 'modified efficiency target' would correspond to emissions level M^{H^*}.

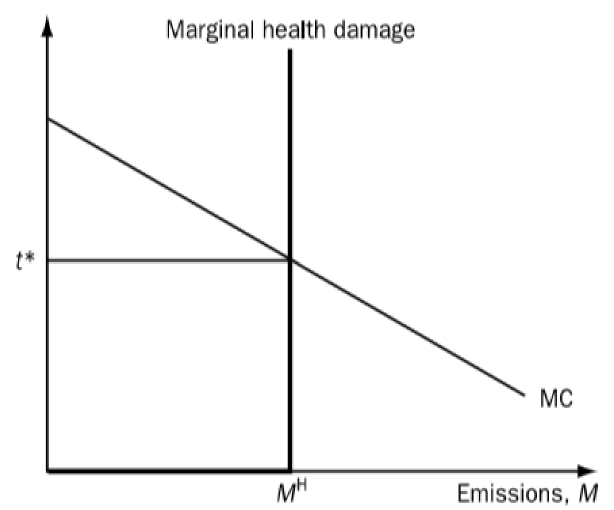

Fig. 4.5a Setting targets according to an absolute health criterion. Source: Perman et al., p.175

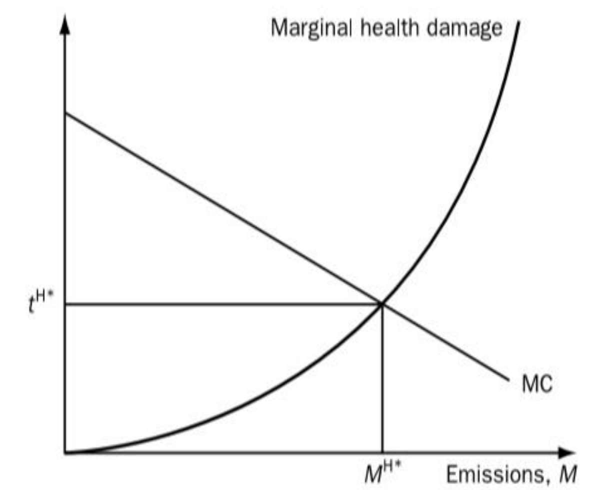

Fig. 4.5b A 'modified efficiency-based' health standard. **Source:** Perman et al.2003, p.175

4.2.1.2 No regrets and double dividends from environmental control

It may be possible sometimes to achieve environmental objectives at no cost or, better still, at 'negative' cost. Policies that allow this to be achieved has been labelled as ***'no regrets' policies***. There are several reasons why these may arise:

- double dividends;
- elimination of technical and economic inefficiencies in the energy-using or energy-producing sectors;
- induced technical change;
- achievement of additional ancillary benefits, such as improved health or visual amenity.

The double dividend hypothesis posits that an environmental policy could produce double benefits by reducing environmental damages and also providing revenue that could be used to reduce other taxes thereby creating efficiency gains for the economy. For example, the revenues from an emissions tax (or a system of permits sold by auction) could be earmarked to reduce marginal rates of other taxes in the economy. If those other taxes have distortionary (i.e. inefficiency-generating) effects, then reducing their rate will create efficiency gains.

An environmental programme that requires firms to use new, less polluting techniques which they may not be aware of but which, nevertheless, are more efficient, or which provides incentives for them to do so, can generate a different kind of double benefit. Pollution is reduced and productive efficiency gains are made. One special case of this is dynamic efficiency gains, arising through induced technical change. It has long been recognized that some forms of regulatory constraint may induce firms to be more innovative (Porter's hypothesis, see Module 7.3). If a pollution control mechanism can be devised that accelerates the rate of technical change, then the mechanism may more than pay for itself over the long run.

4.2.2 The Efficient Allocation of Pollution: Stock Pollutants

For stock pollutants, pollution damage depends on the stock level of the pollutant. In the special (but highly unlikely) case where the pollutant stock in question degrades into a harmless form more-or-less instantaneously, the flow pollution model also provides correct answers to determining the efficient level of pollution. If the stock dimension is distinguishable from the flow only by some constant of proportionality, and so we can work just as before entirely in flow units. But in all other cases of stock pollutants, the flow pollution model is invalid.

This has implication for environmental policy. While the damage is associated with the pollution stock, that stock is outside the direct control of policy makers. Environmental protection agencies may, however, be able to control the rate of emission flows. Even where they cannot control such flows directly, the regulator may find it more convenient to target emissions rather than stocks. Given that what we seek to achieve depends on stocks but what is controlled or regulated are typically flows, it is necessary to understand the linkage between the two.

As indicated earlier, the analysis of stock pollution necessitates taking account of space (spatial dimension) and time (intertemporal dimension). We can distinguish between pollutants with a relatively short residence time (of the order of a day or so) and those with considerably longer lifetimes (years rather than days, let us say).

4.2.2.1 Spatial Implications of stock pollutants

Here we consider pollution control where damages depend on location of the emissions. The focus is on stock pollutants which have relatively short residence times in the environmental media into which they are dumped. Figure 4.6 provides a graphic illustration. There are two polluting *sources*, S1 and S2, that are located near four urban areas, R1, R2, R3 and R4 9 which we call *receptors*. These areas contain populations whose health is adversely affected by local ambient concentrations of the pollutant. We are interested in the amount of pollution the receptors receive from the emission sources. We assume that there is no long-term accumulation effect. Atmospheric processes break up and degrade concentrations rather quickly, so that emissions from the two sources persist for at most a few days. Thus on any one day, pollutant concentrations are determined purely by emissions of the last few days.

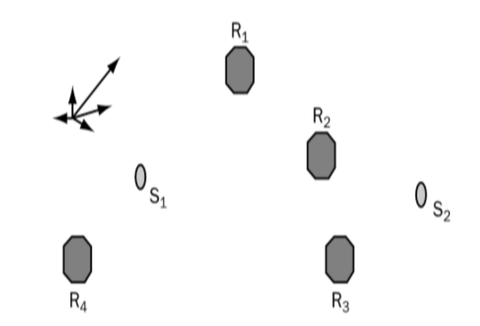

Fig. 7.6. A spatially differentiated airshed. Source: Perman et al., p.178

We need to know how the pollutant mixes across the regions. Mixing of a pollutant refers to the extent to which physical processes cause the pollutant to be dispersed or spread out. One possibility is that emissions are '**uniformly mixing**' (UM). A pollutant is uniformly mixing if physical processes operate so that the pollutant quickly becomes dispersed to the point where its spatial distribution is uniform. In other words, the measured concentration rate of the pollutant does not vary from place to place. This is the case with most greenhouse gases (GHGs).

4.2.2.2 Uniformly-mixing stock pollutants with short residence times

When pollutants are UM, the location of the emission source is irrelevant for the spatial concentration of pollution. Irrespective of the source location, pollutant stocks become evenly distributed across the whole spatial area. So, what matters as far as concentration rates at any receptor are concerned, is the total amount of those emissions. In this case, the simple flow pollution model can be used with minor modification to derive the efficient level of pollution. The modification relates to the relationship between the level of emissions of the pollutant (M) and the pollutant stock size (A). This relationship is now determined by a factor of proportionality, k, such that

$$A = kM \qquad (4.3)$$

with k fixed for any particular kind of pollution. Therefore, while damage is a function of the stock, and benefit is a function of flow, the damage function, (4.2), can be translated into an equivalent flow function using (4.3), that is

$$D = D(kM) \qquad (4.4)$$

When pollutants are not uniformly mixing or when they have relatively long lifespans, it will not be possible to use the flow pollution model to determine the efficient level of pollution. In the former case (where pollutants are not uniformly mixing), the location of pollution source will matter for the spatial concentration of the pollution and it will be impossible to have a single relationship between emissions and concentration over all space. A given total value of M will in general lead to differentiated values of A across receptors. Moreover, if M remained constant but its source distribution changed then the spatial configuration of A would also change. Most air, water and ground pollutants are not uniformly mixing. Examples of non-uniform mixing air pollution problems include ozone accumulation in the lower atmosphere, oxides of nitrogen and sulphur in urban airsheds, particulate pollutants from diesel engines and trace metal emissions.

For non-uniform mixing pollutants, it could be possible to regulate the environmental problem by controlling *ex ante* the location of pollution creators and victims. This approach, implemented primarily by zoning and other forms of planning control, forms a substantial part of the longer-term way of dealing with spatial aspects of pollution. However, where the location of polluters and people are already determined, and moving either is not a feasible option, the attention would focus on determining targets for emissions (the efficient level of pollution) from the various sources.

4.2.2.3 Non-uniformly-mixing stock pollutants with short residence times

Suppose that there are *J* distinct receptors, each being indexed by the subscript *j* (so j = 1, 2, . . ., *J*) and *N* distinct pollution sources, each being indexed by the subscript *i* (so *i* = 1, 2, . . ., N). Various physical and chemical processes determine the impact on pollutant concentration in any particular receptor from any particular source. For simplicity, we assume that the relationships are linear[2]. In that case, a set of constant 'transfer coefficients' d_{ji} can be defined. This describes the impact on pollutant concentration at receptor *j* attributable to source *i*. The total level, or concentration rate, of pollution at location *j*, A_j will be the sum of the contributions to pollution at that location from all N emission sources. This can be written as

$$A_j = \sum_{i=1}^{N} d_{ji} M_i \qquad (4.5)$$

where M_i denotes the total emissions from source i.

Assume as in Figure 4, there are N=2 sources and J=4 receptors, then we will have four equations corresponding to equation 4.5 which are given as

$$A_1 = d_{11}M_1 + d_{12}M_2 \qquad (4.6a)$$

$$A_2 = d_{21}M_1 + d_{22}M_2 \qquad (4.6b)$$

$$A_3 = d_{31}M_1 + d_{32}M_2 \qquad (4.6c)$$

$$A_4 = d_{41}M_1 + d_{42}M_2 \qquad (4.6d)$$

[2] This is a very good approximation for most pollutants of interest but may not apply in a few cases, such as low-level ozone accumulation.

Using matrices, we can express this in compact from as

A = DM

$$\begin{bmatrix} A_1 \\ A_2 \\ A_3 \\ A_4 \end{bmatrix} = \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \\ d_{31} & d_{32} \\ d_{41} & d_{42} \end{bmatrix} \begin{bmatrix} M_1 \\ M_2 \end{bmatrix} \qquad (4.7)$$

Knowledge of the **M** vector and the **D** matrix then allows us to calculate ambient pollution levels, **A.** As in previous cases, the socially efficient level of emissions from each source is the set of emission levels that maximizes net benefits. This will consist of N values of M_i, one for each source. Efficiency in this case implies setting the emissions target (or standard) for each firm so that the private marginal benefit of its emissions is equal to the marginal damage of its emissions.

$$B_i{}'(M_i) = \sum_{j=1}^{J} D_j'\,(A_j)d_{ji} \qquad (4.8)$$

$$\text{for } i = 1 \ldots \text{N}$$

where $B_i'(M_i) = \frac{\partial B_i}{\partial M_i}$ and $D_j'(A_j) = \frac{\partial D_j}{\partial A_j}$

Note that because the i^{th} firm's emissions are transferred to some or all of the receptors, the marginal damage attributable to the firm is obtained by summing its contribution to damage over each of the *J* receptors.

An interesting property of the solution to equation set (4.8) is that not only will the efficient emission level differ from firm to firm, but also the efficient ambient pollution level will differ among receptors. All else being equal, firms located at sources with the highest pollution impact would be required to emit the least. At the same time, those receptors which would (in an unconstrained world) experience the highest pollution-stock level should have the highest efficient ambient pollution level. These two considerations have to be met jointly.

In practice, environmental regulators might deem that it is unethical for the pollution from firms to vary from place to place. So, they might impose an additional constraint on the problem to reflect this ethical position. One form of constraint is that the pollution level in no area should exceed some maximum level A^*(that is $A_j^* \leq A^*$ for all *j*). The imposition of an additional constraint will lead to a lower maximized net benefit from pollution (it will be associated with an efficiency loss). This efficiency loss is what is traded for the goal sought (in this case, greater equity in pollution level across firms).

4.2.2.4 Uniformly-mixing stock pollution with relatively long active lifespan

For these class of pollutants, the uniformly mixing assumption implies that pollutant concentrations will not differ from place to place, and so the spatial dimension of emissions control is no longer of direct relevance. Second, persistence of pollution stocks over time means that the temporal dimension is of central importance. Thus, an efficient pollution control programme will need to take account of the trajectory of emissions over time, rather than just at a single point in time. In other words, an efficient allocation of a stock pollutant **with relatively long active lifespan** must take into account the fact that the pollutant accumulates in the environment over time and that the damage caused by its presence increases and persists as the pollutant accumulates. By their very nature, the pollutants create an interdependency between the present and the future, since the damage imposed in the future depends on current actions. Hence analysis of efficient level of pollution must be cast within a dynamic framework. This is similar to what we learnt under efficient allocation of a depletable resource.

Assume a commodity, X, the production of which involves the generation of a proportional amount of a long-lived stock pollutant (that is, X is produced jointly with the stock pollutant; reducing the amount of pollution will require taking some resources away from the production of X). Assume further that the damage caused by the presence of the pollutant in the environment is proportional to the size of the accumulated stock. As long as the stock of pollutants remains in the environment, the damage persists. As usual, the dynamic efficient allocation maximizes the **present value** of the net benefit where the net benefit at any point in time, t, is equal to the benefit received from the consumption of X minus the cost of the damage caused by the presence of the stock pollutant in the environment. Both benefit and cost of damages increases as more X is produced.

As in the case of depletable resource, the efficient quantity of X (and therefore, the addition to the accumulation of the pollutant in the environment) would decline over time as the marginal cost of the damage rises (counterpart of declining extraction profile) while the price of X would rise over time, reflecting the rising social cost of production (counterpart of increasing price profile). As was the case with rising extraction cost in the case of depletable resources, technological progress could modify the efficient allocation, for example, by reducing the amount of pollutant generated per unit of X produced, or by creating ways to recycle the stock pollutant rather than injecting it into the environment; or by introducing ways of rendering the pollutant less harmful. Each and all of these would lower the marginal damage cost associated with a given level of production of X so that more of X could be produced for a given level of pollution.

As it is with depletable resources, stock pollutants with relatively long active lifespan also raise intergenerational equity concerns. Damages persist well after the benefits received from incurring the damages have been forgotten and these are passed on to future generations.

Given that damage at time t is determined by the contemporaneous stock size or concentration rate of the pollutant in a relevant environmental medium (A_t) and that gross benefits depend on the flow of emissions (M_t), we can represent the damage and (gross) benefit functions by

$$D_t = D(A_t) \qquad (4.9)$$

$$B_t = B(M_t) \qquad (4.10)$$

With relatively long-lived pollutants, emissions add to existing stocks and those stocks accumulate over time. In addition, except in the special case where pollutants are infinitely long-lived, part of the existing stock will decay or degrade into a harmless form over time, thereby having a negative impact on stock accumulation. This stock–flow relationship is often represented in a differential equation, such as

$$\acute{A}_t = \frac{dA}{dt} = M_t - \alpha A_t \qquad (4.11)$$

$$0 \leq \alpha \leq 1$$

Emission at time t, M_t, increases the stock of pollution, A_t. However, some of the existing sock are transformed into harmless substances by physical or chemical processes, or absorbed into oceans or other sinks where it has no damaging effect. The amount of pollution decay is captured by the term $-\alpha A_t$ where α is the *rate of decay or assimilation*. The net effect on A (and so whether A_t is positive or negative overall) depends on the magnitudes of the two terms on the right-hand side of equation 4.11.

- If α = 0, the pollutant exhibits no decay and the rate of stock accumulation ($\acute{A}_t$) is just equal to the flow of emission(M_t). Damages arising from current emissions will last indefinitely and the pollution stock and pollution damages will increase without bounds through time as long as M is positive. The stock at any time (which can be gotten from finding the integral of 7.11 is the sum of all previous emissions. Pollutants with this feature are known as a *perfectly persistent pollutant*. Approximate examples are some synthetic chemicals, such as heavy metal residuals, and toxins such as DDT and dioxin.

- If α = 1, we have instantaneous decay, which means the pollutant can be regarded as a flow rather than a stock pollutant.

- For the more general case of *imperfectly persistent pollutant*, we will expect to find 0 < α < 1. Here, the pollutant stock decays gradually over time, being converted into relatively harmless elements or compounds. An example, for which α is very low is Greenhouse gases (GHGs).

We have assumed that α is constant (that is a constant proportion of the pollution stock decays over any given interval of time). However, this may be invalid in practice, as we may have situations where the decay rate changes substantially over time, or varies with changes in either A or M.

Integrating equation 7.11 over time we obtain

$$A_t = \int_{\tau=t_0}^{\tau=t} (M_t - \alpha A_t) d\tau \qquad (4.12)$$

where t_0 denotes the first point in time at which the pollutant in question was emitted.

We can use this framework to address the problem at hand. Assume now that the policy maker aims to maximize discounted net benefits over some suitable time horizon (an infinite span, for example). Using t = 0 to denote the current period of time using the definition of gross benefits and damages in 4.8 and 4.9, the policy maker's objective is to select M_t for t = 0 to t = ∞ to maximize

$$\int_{t=0}^{t=\infty} (B(M_t) - D(A_t)) e^{rt} dt \qquad (4.13)$$

where r is the social (consumption) discount rate.

A complete description of efficient stock pollution will consist of a trajectory (or time path) of, emission levels through time. In general, this optimal trajectory will be one in which emission levels vary throughout time. However, in many circumstances, the trajectory will consist of two phases: *a steady state* in which emissions (and concentration levels) remain constant indefinitely at some level; and an *adjustment phase*; a path which shows how emissions (and concentrations) move from current levels to their efficient, steady-state levels. This adjustment process may be quick, or it may take place over a long period of time.

Obtaining the optimal trajectory of emission from (4.13) involves the application of the calculus of optimal control. This is outside the scope of this lecture material; hence we focus on describing one of the results: the efficient steady-state pollution level. In the steady state[3], the pollution flow and the pollution stock are each at a constant, unchanging level. Hence the time subscripts we have attached to variables become redundant and can be dropped. Moreover, with an unchanging stock A_t= 0 and so equation 4.11 simplifies to M = αA.

This result is intuitive. For a pollutant that accumulates over time, the pollution stock can only be constant if emission inflows to the stock (M) are equal to the amount of stock which decays each period (αA). Thus, in a steady state, the stock–flow relationship between A and M can be written as

[3] The term steady state is sometimes used to connote a state in which all variables of interest in some system are growing at a constant rate. This is not the idea here. Also, while we have assume the existence of a steady state, such may not always exist.

$$A = \frac{M}{\alpha} \qquad (4.14)$$

Equation (4.14) shows that in a steady state, the smaller is the value of α the larger will be the pollution stock for any given level of emissions. In general, an efficient steady-state level of pollution emissions requires that the following condition be satisfied:

$$\frac{dB}{dM} = \frac{dD}{dA}\left(\frac{1}{r+\alpha}\right) \qquad (4.15)$$

Equation 4.15 is a variant of the familiar marginal condition for efficiency requiring that the marginal benefit and the marginal cost of the chosen emissions level should be equal. More precisely, it can be read as an equality between the present value of the gross benefit of a marginal unit of pollution (the left-hand side of 4.15) and the present value of the damage that arises from the marginal unit of pollution (the right-hand side of 4.15).

Note that a marginal emission today has benefits only today, and so the present value of that marginal emission is identical to its current marginal benefit. In contrast, the damage arising from the marginal emission takes place today and in future periods. The 'discount factor' 1/(r +α) has the effect of transforming the single period damage into its present-value equivalent. At the level of M that satisfies equation 7.15, the value taken by the expression on each side of the equation is known as the *shadow price* of a unit of emission.

Two very important deductions can be gotten from (4.15)

- *Other things being equal, the faster is the decay rate, the higher will be the efficient level of steady-state emissions*: for any given value of dD/dA, a rise in α implies that the value of dB/dM would have to fall to satisfy the marginal equality. A lower value of dB/dM implies higher emissions. Intuitively, the greater the rate of decay, the larger the 'effective' discount rate applied to the marginal stock damage term and so the smaller its present value. A higher discount rate means we attach less weight to damages in the future, and so the emission level can be raised accordingly.

- *Other things being equal, the larger is the consumption discount rate, the higher will be the efficient level of steady-state emissions*: For any given value of dD/dA, a rise in r implies that the value of dB/dM would have to fall to satisfy the marginal equality. A lower value of dB/dM implies higher emissions. Intuitively, the greater is the consumption discount rate *r*, the larger is the discount rate applied to the stock damage term and so the smaller is its present value. A higher discount rate means we attach less weight to damages in the future, and so the emission level can be raised accordingly.

The second observation has significant implication for policy respecting long or infinitively lived stock pollution. Often there will be need to decide on the appropriate social discount rate to apply in determining efficient or desirable pollution targets. As it turns out, the choice of an appropriate discount rate can itself be controversial.

4.3 Pollution in Africa

Pollution includes water, air and land pollution. A major cause of water pollution in Africa is the throwing of general waste into local bodies of water. Communities in poverty do not usually have the funding to create proper waste-management systems so they pollute their water supplies instead. Once a water source suffers pollution, the contaminants can spread into the soil that supplies food and economic activity. For example, people have found metals from local waste in the soil of major agricultural plots of land.[4]

Air pollution is a major problem throughout the world with over 90 percent of people living in places that do not meet the World Health Organization's (WHO's) air quality guidelines[5]. It has also become the biggest environmental risk to Africa currently. The 2019 Global Environmental Outlook (UN, 2019) confirmed that both outdoor and indoor air quality is deteriorating rapidly in many areas in Africa due to various factors, such as the use of firewood and other biomass as sources of energy, increasing traffic volumes, importation of old second-hand vehicles, and increased use of the two-stroke engine motorcycles as alternative means of transport in both urban and rural areas.

Africa's air pollution problem differs from that found in many developed countries. For example, air pollution in cities, such as London, is mainly due to the burning of hydrocarbons for transport, but in African cities, such as Lagos, air pollution is due to the burning of rubbish, cooking indoors with inefficient fuel stoves, millions of steel diesel electricity generators, cars which have had the catalytic converters removed and petrochemical plants, all pushing pollutants into the air over the cities. In addition, compounds such as sulphur dioxide, benzene and carbon monoxide, that haven't been issues in western cities for decades, may be a significant problem in African cities[6].

Multinational companies and trade activities are continuing to add to the pollution in Africa. Governmental enforcement of laws requiring business and trading activities to be more environmentally friendly is low. Companies and trading activities cause the release of gas, oil spills, dangerous chemicals, and waste accumulating on the ground or in water thus increasing

[4] https://www.washingtonpost.com/business/energy/air-pollution/2019/11/06/9487ebfe-007b-11ea-8341-cc3dce52e7de_story.html.

[6] https://www.theguardian.com/global-development/2016/oct/20/air-pollution-deadlier-africa-than-dirty-water-or-malnutrition-oecd

air and water pollution. Air pollution from coal releases dangerous gases that can poison plants, contaminate communities and produce acid rain. Unlike many other countries outdoor air pollution is growing at a fast pace in Africa. This is in spite of slow industrialization in many countries. And unless radically new approaches and technologies are put to use, the situation may be worse in future if many other countries pick up on industrialization. In addition, while many major environmental hazards have been improving with development gains and industrialization, outdoor (or "ambient particulate") air pollution from traffic, power generation and industries is increasing rapidly in Africa, especially in fast-developing countries such as Egypt, South Africa, Ethiopia and Nigeria.[7]

According to reports by the Organization for Economic Co-operation and Development, annual human and economic cost of tainted air runs to 712,000 lost lives and £364bn.[8] The Continent's air pollution is causing more premature deaths than unsafe water or childhood malnutrition, and could develop into a health and climate crisis.[9] For Africa as a whole, the estimated economic cost of premature air pollution deaths in 2013 was roughly $215bn (£175bn) a year for outdoor air pollution, and $232bn for household, or indoor, air pollution. Annual deaths from ambient (outdoor) particulate matter pollution across the continent increased by 36% from 1990 to 2013. Over the same period, deaths from household air pollution also continued to increase.[10]

One of the factors driving increasing pollution is urbanization and growth of urban slums. According to the World Health Organization (WHO), global urban air pollution levels increased by eight per cent between 2008 and 2013. This is expected to rise given the increasing level of migration to urban areas, which will likely lead to more human activities and more pollution. More than 80 per cent of people living in urban areas are exposed to air pollution levels that exceed WHO limits, threatening lives, productivity and economies. Indeed, Africa urbanizes at a very fast pace: today's 472 million urban dwellers will be around a billion in 2050. In Africa, the increasing level of urbanization coupled with poor urban planning leads to large

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7 https://www.theguardian.com/global-development/2016/oct/20/air-pollution-deadlier-africa-than-dirty-water-or-malnutrition-oecd

8 https://www.theguardian.com/global-development/2016/oct/20/air-pollution-deadlier-africa-than-dirty-water-or-malnutrition-oecd. Other sources suggest an estimated 600,000 deaths https://www.unenvironment.org/news-and-stories/story/air-pollution-africas-invisible-silent-killer-1; https://www.who.int/quantifying_ehimpacts/publications/PHE-prevention-diseases-infographic-EN.pdf?ua=1).

9 Estimates suggest that dirty air could be killing 712,000 people a year prematurely, compared with approximately 542,000 from unsafe water, 275,000 from malnutrition and 391,000 from unsafe sanitation (https://www.dw.com/en/west-africa-struggles-with-rise-in-pollution/a-49965986; https://www.theguardian.com/global-development/2016/oct/20/air-pollution-deadlier-africa-than-dirty-water-or-malnutrition-oecd).

10 Ibid.

numbers of people living in congested and poorly-serviced housing. This serves to exacerbate the problem of pollution. It is believed that the human and economic costs of air pollution in the continent might “explode” without bold policy changes in Africa’s urbanization policies.[11] Figure 7.7 shows that urban vulnerability is already very high in many countries in Africa.

According to some authors, “the ‘new’ problem of outdoor air pollution in Africa is too large to be ignored or deferred to tomorrow’s agenda. At the same time, Africa cannot afford to ignore the ‘old’ problem of household pollution or to consider it largely solved: it is only a few high-income countries – Algeria, Egypt, Libya, Mauritius, Morocco, Seychelles and Tunisia – that can afford to view the problem of air pollution as being a problem of outdoor particulate pollution alone.” Overall, it is obvious that current means of transportation and energy generation in African cities are not sustainable. It is also not an easy choice. For example, whereas countries, such as China has reached a level of development that has allowed it to concentrate on solving air pollution, most African countries must grapple with several major environmental burdens (including unsafe water or unsafe sanitation or underweight children) at the same time.[12] In summary, among other things, African governments need to develop the political will to introduce and implement laws that limit pollution and also adopt medium and long term measures to acquire clean energy.[13]

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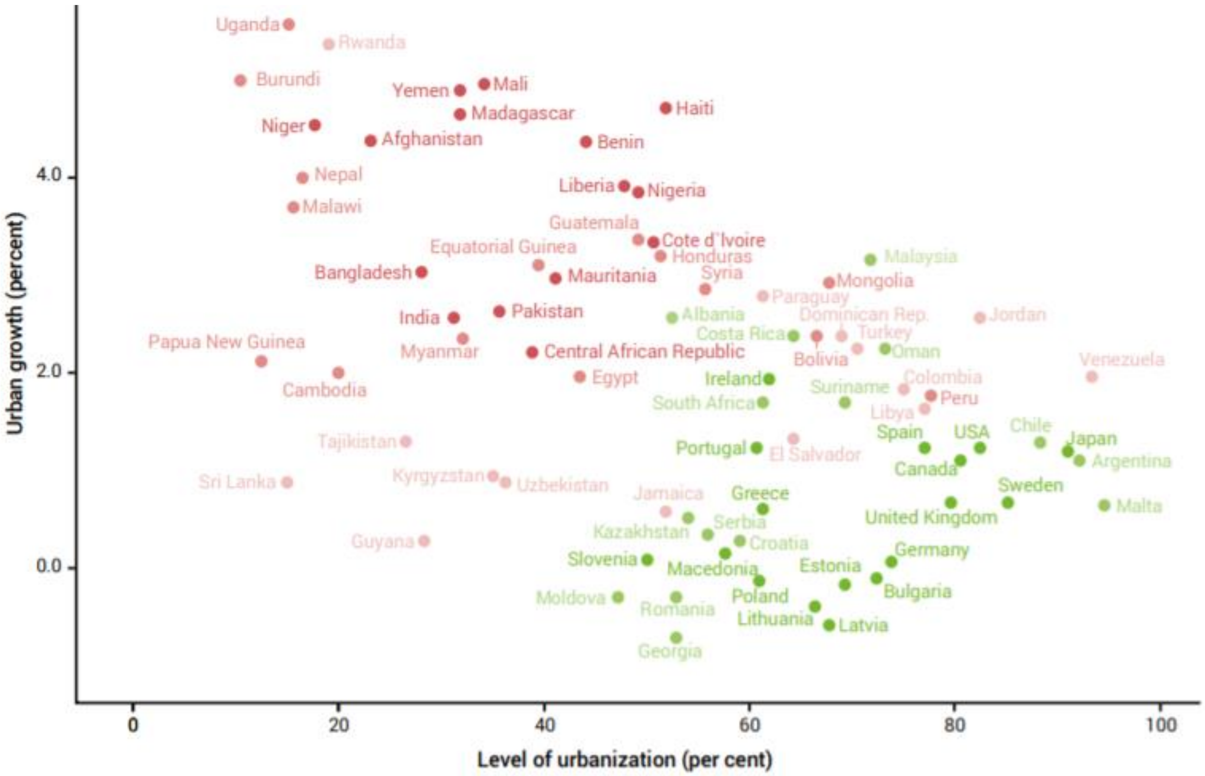
[11] https://www.theguardian.com/global-development/2016/oct/20/air-pollution-deadlier-africa-than-dirty-water-or-malnutrition-oecd; https://www.unenvironment.org/news-and-stories/story/air-pollution-africas-invisible-silent-killer-1

[12] Ibid.

[13] https://www.unenvironment.org/news-and-stories/story/air-pollution-africas-invisible-silent-killer-1



Classes of urban vulnerability	Level of urbanization	Growth rate 2000-2015
Very low	75.80	0.71
Low	69.19	0.92
Medium	56.07	2.36
High	43.51	2.89
Very high	38.59	3.71

Fig. 4.7 Urbanization and urban vulnerability. **Source:** Garschagen et al. (2014).in UN (2019), p.34.

Summary

- An environmental problem emerges when the rate of waste discharge into the environment exceeds its assimilative capacity (a pollution problem) and/or when a renewable resource is harvested beyond its regenerative capacity so that the ecosystem functions are affected negatively.

- Pollution is not only a problem by itself, it impairs all the other estuarine functions of the environmental resource base (ERB). Society needs to decide what pollution level should be accepted and how this should be allocated among the various sources.

- Economic efficiency is often proposed as a more realistic goal for setting pollution targets. What exactly is the efficient allocation of pollution will depend on the nature of the pollutant and the associated damages. Different types of pollutants have different damage mechanism and hence differing impact on the absorptive capacity of the environment. They will therefore require different policy responses. Good public environmental policy requires an understanding of the nature of various pollutants, their effects on the environment, and their costs.

- Stock pollutants are pollutants for which the environment has little or no absorptive capacity. Such pollutants accumulate over time as emissions enter the environment. Fund pollutants are pollutants for which the environment has some absorptive capacity. These pollutants will generally not accumulate as long as the emissions rate does not exceed the absorptive capacity of the environment.

- The zone of influence of a pollutant also matters. Horizontal dimension of influence refers to the spatial domain over which damage from an emitted pollutant is experienced (local, regional, global), while the vertical zone of influence shows whether pollution damage is caused mainly by ground-level concentrations of an air pollutant or by concentrations in the upper atmosphere.

- The efficient allocation for a fund pollution is at the point where the marginal damage cost is equal to the marginal control (abatement) cost.

- In some circumstances, society or policy makers may consider a particular effect or cost of pollution of primary importance, such as its effect on human health. In this case, pollution costs would be defined in terms of that effect alone. That leads to a revised or modified efficiency criterion in which the goal is to maximize the difference between all the benefits of pollution and this particular kind of pollution damage.

- The analysis of stock pollution necessitates taking account of space (spatial dimension) and time (intertemporal dimension). Also important is the active lifespan of the pollutant.

- For uniformly-mixing stock pollutants with relatively short active lifespan, the location of the emission source is irrelevant for the spatial concentration of pollution, so the simple flow pollution model can be used with minor modification to derive the efficient level of pollution. However, most air, water and ground pollutants are not uniformly mixing.

- For non-uniform mixing pollutants with relatively short active lifespan, it could be possible to regulate the environmental problem by controlling ex ante the location of pollution creators and victims. This approach, implemented primarily by zoning and other forms of planning control, forms a substantial part of the longer-term way of dealing with spatial aspects of pollution. However, where the location of polluters and people are already determined, and moving either is not a feasible option, the attention would focus on determining targets for emissions (the efficient level of pollution) from the various sources.

- In this case, the efficient emission level will differ from firm to firm, and the efficient ambient pollution level will also differ among receptors. All else being equal, firms located at sources with the highest pollution impact would be required to emit the least. At the same time, those receptors which would (in an unconstrained world) experience the highest pollution-stock level should have the highest efficient ambient pollution level.

- An efficient allocation of a stock pollutant with relatively long active lifespan must take into account the fact that the pollutant accumulates in the environment over time and that the damage caused by its presence increases and persists as the pollutant accumulates.

- In this case, the dynamic efficient allocation maximizes the present value of the flow of net benefits, where the net benefit at any point in time, t, is equal to the benefit received from pollution activity minus the cost of the damage caused by the presence of the stock pollutant in the environment.

- In this case, the choice of an appropriate discount rate can itself be controversial. In addition, stock pollutants with relatively long active lifespan raise intergenerational equity concerns.

- Air pollution is arguably the most serious environmental risk facing Africa today.

Discussion/Review Questions and Exercises

1. What is the significance of the distinction between stock and flow pollutants in the formulation of environmental policy? Provide an example each of a stock and a flow pollutant.

2. Explain the concept of the 'efficient level of pollution'. What information is required in order to identify such an efficient quantity?

3. What differences and considerations are relevant for determining the efficient level of pollution for a uniformly-mixing stock pollutant and a non-uniformly-mixing stock pollutant with relatively short active lifespan?

4. What considerations come into determining the efficient level of pollution for a stock pollutant with a relatively long active life span?

5. Discuss the following propositions

   (a) 'Only the highest standards of environmental purity will do.'
   (b) 'A clean environment is a public good whose benefits cannot be privately appropriated. Therefore, private industry which is run for private gain will always be the enemy of a clean environment.'

6. Using equation (7.15), deduce the effect of
   (i) a decrease in α and
   (ii) an increase in r (ceteris paribus) on

   (a) M^* (b) A^* (c) μ^*

7. What is the most important pollution problem in your country? What are the drivers and what do you think can be done to address it?

Materials used for this Module

1. Perman, R., Ma Y., McGilvray J. and Common M. (2003). **Natural Resource and Environmental Economics,** 3rd edition**.** Edinburgh, Longman.

2. Tietenberg, T. & Lewis, L. (2012). Environmental & Natural Resource Economics 9th Edition, The Pearson Series in Economics.

3. UN Environment (2019). Global Environment Outlook – GEO-6: Healthy Planet, Healthy People. Nairobi. DOI 10.1017/9781108627146.

Module 4.2: Environmental and Natural Resource Management Policy Instruments (4.5 hours)

Learning Outcome

This Module provides a discussion on Policy Instruments that are potentially available to governments to use to address environmental and natural resource problems. After going through this module, you should be able to

- ✓ Know the two broad divisions of policy instruments available for regulating environmental problems.
- ✓ Identify the main command and control instruments for environmental and natural resource management.
- ✓ Explain how command and control instrument(s) could be used to help solve environmental problems and the conditions under which they could be effective.
- ✓ Identify the three broad categories of economic instruments available for environmental control.
- ✓ Explain certain advantages of economic instruments and possible objectives that they could achieve.
- ✓ Explain the key features of price-based instruments and when they can be used
- ✓ Explain what property rights-based instruments are and when they can be used
- ✓ Explain the key features of legal, voluntary and information-based instruments for environmental and natural resource management and when they can be used.
- ✓ Understand public provision as an Environmental Policy tool and its limitations.
- ✓ Appreciate the relevance of second-best theory in environmental and natural resource policy, and especially in the context of Sub-Sharan Africa.

Content Outline

4.1.1 Introduction

Where the government has the will, means and capacity to address environmental and natural resource management problems, it will still need to find and use appropriate policy tools to achieve the purpose. The policies available to redress environmental problems fit into two broad classes: command and control instruments and economic instruments.

Command and Control Instruments are the laws and regulation used by governments to directly control pollution and manage natural resources. In the application of these instruments, the government stipulates the technologies that must be used to curb pollution, determines the maximum amount of emissions that is permissible, and regulates the use of natural resources. Polluters have little or no flexibility in the application of command and control instruments as the laws and regulations must be observed uniformly as stipulated by all agents. To ensure compliance, the government is required to monitor enforcement and prosecute offenders in a court of law. This usually requires detailed information about regulated industries, since the government must understand the details of industrial technologies.

Economic instruments provide market and financial incentives for polluters and natural resource users to change their behaviour by making pollution and overuse of natural resources more costly. In economic terms, economic instruments internalize externalities (environmental costs) through increasing the prices that individuals and industries must pay to use resources or to emit pollutants. As pollution or the use of natural resources become more expensive, polluters and consumers have strong financial incentives to reduce such activities through conservation, substitution of materials, or rationalizing consumption.

Both command and control and economic instruments attempt to shift the costs and responsibilities associated with pollution or over exploitation back to the polluter or users (the Polluter Pays Principle, PPP). The differences between the two policy types, however, are significant in terms of cost and effectiveness. Economic instruments possess a number of inherent advantages over command and control instruments for many problems. They are generally more affordable, flexible, responsive, and encouraging to technology innovation. In addition, although economic instruments cannot overcome a corrupt or weak political structure, they can help make moderately functioning governance structures work more effectively. As such they try to minimize possible policy and institutional failures.

In practice, economic instruments are used together with command and control instruments to increase policy efficiency, and achieve environmental targets at a lower cost. Economic instruments can complement rather than fully replace command and control policies, offering many potential applications even in countries with substantial policy constraints. However, combining policy elements requires care since the elements can sometimes work at cross-purposes.

4.1.2. Command-and control Instruments

Command and control (CAC) policies for environmental regulation include those that regulate technology and those that regulate performance.

4.1.2.1 Regulation of Technology

The regulation of technology allows governments and their environmental agencies to ban or restrict specific technologies that cause pollution or deplete natural resources. Conversely, they may require the use of technologies that reduce emissions or prevent overuse of natural resources. The two policy options in this category are the designation (specification) of technology and zoning.

(i) Designating Technologies:

By designing a standard, the regulator (typically the government through its environmental protection agency) can prescribe the technology that firms and households have to use, prevent the use of some technology altogether, or prescribe the conditions under which a polluting technology can operate. For example, regulations may require the use of the "best available" or "state-of-the-art" technology to ensure that polluters adopt improvements as technology changes. As an illustration, consider the case where public service minibuses are emitting a lot of smoke yet simple observation may show that other minibuses do not emit as much smoke. The regulator can therefore require the polluting minibus to cut down on its smoke emissions using available cleaner technology.

(ii) Zoning

In some cases, governments or its environmental agencies may restrict the location of the use of technology. To do this they use zoning laws to regulate where firms may use certain technologies because they generate excess noise, odours, or potential exposure to hazardous materials in populated areas. On the other hand, these same technologies may be zoned for use in areas where the effects can be absorbed without excessive damage to the environment or natural resources.

Mandatory technology design standards are the most commonly used environmental control instruments because they have an intuitive simplicity and they appeal to the desire of policymakers to quickly address (if not solve) the problem at hand. Technology standards have been employed for a whole range of purposes, including automobile emission control (where mandatory installation of catalytic converters on new cars is now almost universal), regulation of nuclear power (where plants are regulated not only by being given maximum emission levels (zero in this case) but are also required to comply with more detailed and specific technology requirements, such as multiple control systems and specific kinds of hazardous material containment), and natural resource management (for example, in fishing where the use of cyanide and dynamite are banned, in agriculture and forestry, where certain pest control techniques are banned, and in some cases replanting of trees after harvest is mandatory).

The regulation of technology through design standards is particularly appropriate when

- Technical and ecological information about the environmental problem to be resolve is complex.
- Crucial knowledge is available at the government rather than at the firm level so that the overall impact of the regulation can be estimated but not the effect at the individual or firm level.
- Firms are unresponsive to price signals (e.g.,a firm could be operating in a non-competitive setting), or investments to improve environmental practices are large and have little benefit to the individual firm.
- Standardization of technology could hold some major advantages for both producers and the general public as in the case of catalytic converters.
- One design or technology is definitely superior to others available, making its mandated implementation the best alternative.
- Monitoring costs are high so that monitoring emissions is more difficult than monitoring technology

Where appropriate, the use of technology regulation can provide clarity of choice, economy of administration, effective control, and ease of monitoring. Design standards are also useful in circumstances, where considerations other than efficiency (e.g., ease of inspection and estimation of effects) may be of overriding concern. In many cases, both regulators and polluters often prefer the use of technology regulation because it is easier to understand and comply with than more indirect methods of pollution control or natural resource management. It also appears intuitively fair because everyone engaged in a certain activity is required to use (or is prohibited from using) the same technology.

However, a major drawback of technology regulation is its inflexibility. Since it is not possible for the regulator to have information about individual abatement levels or appropriate technologies for each firm, the government will designate a standard technology for all polluters (e.g., catalytic converters, filters or chimneys). This prevents a given firm or individual from using an alternative technology even though it may be more effective in a given circumstance. Consequently, firms have little incentive to develop better technology.

4.1.2.2 Regulation of Performance

Rather than requiring or prohibiting particular technologies, the regulation of performance targets individual levels of emissions or natural resource exploitation by imposing directly-enforced government limits on the quantity of emissions or harvest of a renewable resource for each individual or firm. Options in this category includes performance standards, tradable emissions permits, and zero emissions**.**

(i) Performance Standards

Under this approach, the regulating agency chooses the maximum allowable emissions or harvest for each firm or individual polluter. Thus, unlike in the case of technology regulation, firms have some flexibility in the choice of abatement method by which to meet the mandated goal. In addition, firms could choose between reducing output levels and increasing abatement level per unit of production and/or trade-off between polluting units within the organization.

Experience suggest that the regulation of performance can lead to increasingly effective solutions to environmental problems. For example, technology for removing effluent gases from motor vehicle exhausts as government emission performance standards have tightened over time.

(ii) Zero Emissions or total bans

This is a unique type of performance standard that imposes a total ban on particular emissions considered harmful to human health or to endangered species at any positive level. Total bans are most often used for radioactive materials, dangerous pesticides, heavy metals (cadmium, lead) and toxic chemicals as well as the trade in ivory and endangered species. The ease of monitoring may explain the popularity of the use of total bans, even in cases where some level of emission or harvest might be possible.

A potential problem with performance regulation is that controlling individual emissions rates (such as those set for new cars) do not imply full control on total levels of pollution or ambient pollution levels. This is because total pollution levels depend both on the output for each agent and the number of agents operating in the economy. Even if each polluter produces no more than the permitted amount of pollutant, the total pollutant load will exceed desirable levels when there are too many individual polluters. The same is true with natural resources management where the total harvest (e.g. grazing level, fish catch, tree cutting) can become unsustainable if there are too many harvesters, even though each harvester only extracts his or her permitted amount of the resource. In addition, regulation of individual performance can be costly because every individual polluter or user must have his or her emissions or usage inspected.

4.1.3 Economic Instruments

Economic instruments provide financial incentives for polluters and natural resource users to reduce output of pollutants and unsustainable use of natural resources. There are different ways to classify economic instruments (see Panayotou, 1998). A simple and convenient approach is to divide them into three basic types: price-based instruments, property rights-based Instruments, and legal, voluntary and information-based instruments.

4.1.3.1 Price-Based Instruments

These instruments include special government taxes, charges, or fees designed to raise the price of polluting the environment or exploiting natural resources. These policies attempt to set the price for users of environmental and natural resources 'right' to cover the excess social and environmental costs caused by the economic activities of polluters or natural resource users (externalities). Appropriate pricing of resources through price-based instruments sends a more accurate signal to users encouraging more appropriate resource consumption and conservation.

Common price-based instruments are direct taxation, input and output taxation, emission or access charges, refunded emissions payments, deposit refunds, subsidies and removal of perverse subsidies.

Direct taxation involves the use of Pigouvian taxes in the case of pollution. In natural resources management, governments use price-based instruments such as mining royalties, stumpage fees (a fee typically charged by the government to logging companies for the right to harvest lumber from public land), user fees (fees charged to users of goods or services provided by the government), and land taxes as variants of Pigouvian taxes. They impose fees and taxes as part of natural resource management policies to correct market failures (any externalities related to resource use) or institutional failure (the absence of property rights). As such, natural resource use fees help reduce and compensate for negative effects - loss of natural resources and inherent pollution caused by mining, forestry, and fishing - and impose a scarcity rent when there is no effective owner who can claim such a rent (as for fish stocks for instance). Fees charged for natural resources use are a considerable source of revenue in low-income countries

The use of Pigouvian taxes requires the regulating authority to be able to determine the marginal damage and the marginal abatement or control cost curves for each pollutant and then set the tax or charge equal to marginal damage at the optimal level of pollution. Such an ideal state of affairs would include having fully informed, honest, welfare-maximizing regulators and appropriate concepts of property rights. In reality, no government or private organization can have all the data needed to know exactly what an appropriate tax would be. So, one cannot find real world situations where the tool is applied as prescribed by the theory. In real world applications, governments adjust pollution taxes, charges, and fees by trial and error to obtain an approximate solution.[14] Further, earmarking environmental tax revenues for environmental

[14] In the practical policy development, medical practitioners, ecologists or environmental engineers (rather than economists) may recommend target levels of pollution or natural resource use without an economic analysis of the marginal costs of the environmental damage. The government then negotiates actual taxation among various interests and imposes them through the political process. In addition, the relatively complex legal process involved in passing and modifying tax laws makes them difficult to be adjusted to changing conditions. Further, when revenues go to the general treasury rather than to a specific trust fund, the effect of the tax instrument in addressing the specific problem is often lost. Local or industrial sector charges (over which polluters or resource users have some influence) are typically more readily acceptable since the money stays within the sector or the region.

purposes may be a controversial issue, especially in developing countries were public funds are often scarce. If the environmental tax itself gives enough incentive to reduce pollution or resource overuse sufficiently, the tax benefits may be diverted to the general treasury. If on the other hand the tax does not give enough incentive to fully solve the environmental problem (which is often the case) it may be argued that tax revenues should be earmarked for environmental purposes such as publicly-financed abatement (e.g. sewage treatment).

Input and Output taxes are levies on some input or output that can be easily monitored and that serves as a good indicator or proxy for the regulated pollution. They are often used in cases where the monitoring of emissions is impossible, difficult or costly, so that the government cannot directly tax the polluting activity. Gasoline taxes and vehicle weight charges are examples that are introduced based on the assumption that the ones paying will also be responsible for car emission and thus cause the environmental harm. The relationship between gasoline consumption and the environmental damage caused by vehicle emissions is far from simple and valuing and monitoring each vehicle is too complex to be practical. Therefore, regulators choose gasoline taxes as a proxy even though unused and contained gasoline itself is not a pollutant. Under differentiated vehicle weight charges, the amount of tax charged on a vehicle depends on its weight. The government bases such charges on the presumption that heavier vehicles are more damaging than the lighter ones. Several counties tax fertilizer rather than attempt to measure the amount of contamination of groundwater sources from each bag sold. Box 4.1 provides an illustration with the imposition of taxes on plastic bags to prevent littering.

Economists sometimes refer to input and output taxes as **presumptive taxes** because, in the absence of direct monitoring, the government presumes that the agent that uses a certain input or produces a certain output is polluting. Some researchers favour the use of presumptive taxes in developing countries where monitoring individual emissions is often impossible. However, while such charges are simpler to administer, it is important to keep in mind that they are not equivalent to emissions charges. Not every unit of the taxed product may have the same impact on the environment. For example, some purchased fertilizer may be used in sensitive areas (and therefore should be heavily taxed to reflect its high marginal damage), while others may be used in areas with lots of natural buffering (and therefore should not be taxed as heavily). Since the normal product charge would be the same per bag, it would not be able to make these kinds of distinctions. Product charges are most efficient when all purchased units of that product cause exactly the same marginal damage. Although full efficiency is probably rarely achieved by product charges, they may be better (even much better) than doing nothing.

Box 4.1 The Irish Bag Levy

Rapid economic growth in Ireland in the 1990s was marked by a significant increase in the amount of solid-waste per capita. The lack of adequate landfill sites resulted in escalating costs of waste disposal, which in turn led to more illegal dumping and littering. It was feared that tourism, one of Ireland's largest industries, would be negatively affected as a consequence of the degradation of the environment. The food industry, which based a significant amount of their marketing strategies on a healthy, wholesome reputation, also suffered as a result of the public perception of their role in the increased litter. The most visible element of litter was plastic bags, so in 2002 the government introduced the Plastic Bag Environmental Levy on all plastic shopping bags, with a few exceptions that were sanctioned for health and safety reasons. Retailers were charged a fee of 15¢ per plastic bag, which they were obliged, by the government, to pass on to the consumer. This levy was designed to alter consumer behavior by creating financial incentives for consumers to choose more environmentally friendly alternatives to plastic, such as "bags-for-life." (Bags-for-life are heavy-duty, reusable cloth or woven bags, which were made available in all supermarkets, at an average cost of €1.27.) Expectations that this levy would bring about a 50 percent reduction in the number of plastic bags used were exceeded when the estimated actual reduction turned out to be 95 percent! In a single year, Irish consumers reduced their consumption of plastic bags from 1.26 billion to 120,000, while concurrently raising approximately €10 million in revenue for the government. Placed in the Environmental Fund, this revenue finances environmental initiatives such as recycling, waste management, and, most importantly, antilitter campaigns. This levy has been viewed as a major success by the government and environmental groups alike. It has also been enthusiastically embraced by Irish consumers, thanks to an intensive environmental-awareness campaign that was launched in conjunction with the levy. Irish retailers, although skeptical in the beginning, have also recognized the huge benefits of this levy. Estimates suggest that their costs were offset by the savings from no longer providing disposable bags to customers free of charge, as well as the profit margin earned on the sale of "bags-for-life," whose sales have increased by 600–700 percent since the introduction of the levy. The amount of plastic being sent to Irish landfills has been dramatically reduced, bringing about a clear visual improvement. The success of this case has promoted the diffusion of this idea. For example, in 2008 China banned super thin plastic bags and imposed a fee on other plastic bags.

Source : Linda Dungan. "What Were the Effects of the Plastic Bag Environmental Levy on the Litter Problem in Ireland?" http://www.colby.edu/~thtieten/litter.htm/; **Source:** Titenberg & Lewis, 2012. p389.

In addition to input and output taxes, governments can use **subsidies** to raise the relative price for polluters compared to non-polluters, e.g. by *offering subsidies*, refunds and other positive payments for improved environmental practices, or by *removing perverse subsidies* (i.e. those that promote environmentally unsound practices). Government subsidies can compensate for the cost of environmentally friendly production and consumption behaviour, and thereby encourage such behaviour.

A subsidy can be either a direct repayment of abatement costs or a fixed payment per unit of emissions reduction. In the latter case, the subsidy serves as a kind of negative tax. If the polluting company is out of business, bankrupt or unidentifiable (as is the case with some historic cases of pollution, particularly in developing or formerly planned economies), then the public sector may have little choice but to finance cleanup with public funds or subsidize other companies to do the cleanup. As such, subsidies can be a practical alternative, particularly when other instruments or incentives to clean up the environment are not feasible. Situations where the polluter expressly owns the property rights to a certain resource that society wants (for example, oil discovered below a private property) can also warrant subsidies. Subsidies are also useful where the government wishes to protect privately owned environmental assets (e.g. land, forests, and waterways) without assuming full ownership or eliminating all private uses. The subsidy instrument does not fulfil the Polluter Pays Principle (PPP) and is, partly for that reason, popular with polluters and owners or potential buyers of polluted property whose activities did not cause the pollution.

The removal of perverse subsidies – i.e. subsidies that promote economic development and stimulate unsound environmental practices (for example, subsidies supporting industries such as fishing, forestry, etc.) – can also have a direct impact on environmental quality. Governments usually provide such subsidies in an effort to achieve some other desirable societal good such as economic development, job creation, protection of a way of life, or relief for the poor. From the environmental economics perspective, it is important to stress that any perverse subsidy distorts markets and hence creates inefficiencies. This leaves a society as a whole with fewer resources to address its problems, no matter which ones are the most pressing. Most perverse subsidies are maintained not because they are the only way to promote a certain policy goal, but rather because the benefiting stakeholders have strong vested interests and prevent changes.

Many observers see removal of such perverse incentives as a far more important issue than providing of subsidies to improve the environment. Such inappropriate subsidies promote rather than prevent wasteful and environmentally destructive behaviour. Combining subsidies with other price-based instruments can be quite effective for environmental and natural resources management. For instance, the government can combine quantity restrictions with a small subsidy for over-compliance or with high fees for pollution emitted above a certain level. Such combinations may serve as a safety valve if regulators are not sure of the optimal pollution pricing level. They may also provide a way to collect information on abatement costs. However, there are two primary problems associated with subsidies as an economic instrument. First, subsidies can be too expensive as a policy instrument especially in developing countries where the opportunity cost of public funds is high. Second, removal of perverse subsidies is often politically complicated because subsidies often go to powerful vested interests.

Under **deposit refund**, the government can exempt polluters that demonstrate abatement or clean technology from taxes or refund presumptive taxes to them. Deposit refund systems involve a charge on some particular item and a subsidy for its return. As such, they are combined instruments of charge and subsidy used to encourage environmentally appropriate recycling. Recycling beverage bottles and cans are the most well-known example but the principal applies to anything (automobiles, chemicals, fluids) that cause environmental damage if not recycled. Deposit refunds, and similar systems, operate on the assumption that the consumer or firm will pollute in the absence of the system; for instance, that people will not recycle bottles without financial incentive to do so. In cases where disposal harms the environment, the deposit refund becomes a tax expenditure on inappropriate disposal. The polluters (those who do not return the item) pay a charge, whereas those who return the item collect a refund and therefore pay nothing. Box 4.2 illustrates the use of deposit refund instrument in Korea, while Box 4,3 illustrates a successful use of refunded emission payments in Sweden.

Box 4.2. Sweden Offers Sulphur Tax Rebates for Abatement

In Sweden a substantial tax is levied on the sulphur content of fuels (over $4 per kg of sulphur) but this is rebated for large emitters who can prove how much sulphur emission they have abated. For large emitters, therefore, the effect of the sulphur tax is precisely the same as the emissions tax; for everybody else the tax on the sulphur content of fuels provides incentives to switch to low-sulphur fuels and to reduce energy use overall. The tax has been extremely effective as it is relatively simple to implement because it can be levied at wholesale level. The national target for sulphur emissions was met several years ahead of the schedule, and the revenue from the tax was actually lower than projected, as a result of the extensive fuel-switching and emission reductions that followed introduction of the tax.

Source: Panayotou T. (1998). Box 4-2, p. 53; UNEP, 2009.

Box 4.3 Korea Adopts a Massive Deposit Refund System

Korea uses an extensive waste disposal deposit refund system which covers food, beverages, liquor bottles and containers, batteries, tyres, lubricating oil, electric home appliances (and any other item that generates toxic waste), bulky or heavy commodities that require treatment, non-degradable materials and harmful household commodities that should not be mixed with the general waste stream. The manufacturer is required to deposit a certain amount for each unit sold, refundable upon collection and treatment.

Source: Panayotou, T. 1998, Box 4-2, p. 56; UNEP, 2009

The distinguishing feature of the deposit refund scheme is that it has a disclosure mechanism; the government or firm pays the refund when the potential polluter demonstrates compliance by returning the item that carries the refund, therefore reducing the need for monitoring of illegal disposal. Refund programmes have spread widely in both developing and developed countries in recent years. In the developed world, the system has very wide applications. For example, Sweden instituted a deposit refund scheme on scrap vehicles to prevent their abandonment in the woods to rust. It is conceivable that governments could use similar instruments to recover other polluting inputs, such as cadmium or mercury (UNEP, 2009). However, the setting up of the deposit refund fee, especially in developing countries where there is no information on the possible reactions of consumers or the environmental impact of some of the wastes, is an iterative process - you have to keep trying to get the deposit refund high enough to stimulate use of the system. This means that it is not possible to know in advance whether a particular fee structure would be successful or not.

Refunded Emissions Payments (REPs) combines charges and subsidies. An REP is a charge imposed on polluting firms, the revenues of which are returned to the same group of polluters, not in proportion to the payments made but in proportion to another measure such as output. The individual firm pays a tax on emissions and receives back a share of the total fees collected based on output. The net effect of the payment and refund is that firms with above average emissions make net payments to the firms that are cleaner than average. In the application of this instrument, the firms with high ratios compensate firms that have a low ratio of emissions to output.

It is believed that REFs can improve pollution control and provide incentives for the adoption of cleaner technology in situations where the government lacks adequate political authority to enforce compliance. Such systems make it easier for politically powerful polluters to comply with environmental regulations. However, they are effectively a market-distorting subsidy, and can even be a perverse subsidy. In the first instance, firms pay for the pollution they produce, which is a pollution charge or tax. In the Pigouvian sense, it corrects for negative externalities caused by the pollution. In the second instance, the raised money is returned to the industry, which is basically a general subsidy for this industry and gives it a comparative advantage with respect to other industries. The main policy advantage of REPs – and of tax-subsidy schemes in general - over taxes, relates to the distribution of cost. Because all firms will pay less and some firms even make money in a REP scheme, it will not create the same kind of resistance (and lobbying) from polluters as taxes often do. The use of refunded emission permits, however, is a relatively new concept and there is little empirical experience around the world.

4.1.3.2 Property Rights-based Instruments

These instruments define, adjust, or create property rights to ameliorate environmental damage by defining the basic enforceable law for ownership and use of both tangible (e.g. land) and intangible (e.g. permits) property. The purpose is to manage the environmental assets by creating, clarifying, and enforcing rights to specific property. Some property rights-based instruments define rights to ownership of existing property. Others create property in the form of tradable permits to use resources or emit pollutants. Both of these instruments give the authorized parties a direct financial stake in the renewable natural resources and environment in general. This, in turn creates self-interest for reducing pollution, for maintaining sustainable harvest rates, and for the direct monitoring and control of illegal activities. More specific instruments include tradable emission permits in pollution management, individual transferable quotas in fisheries management, transferable grazing rights in range management, and transferable development rights in property management.

Clearly defined and enforced property rights, which are established through legal regulations[15], are the foundation of all markets. They provide policy makers with two separate tools. First, their establishment gives the incentive to use existing resources sustainably and efficiently. Second, policy makers can decide how they want to distribute the rights. Taking use of the latter aspect can often help in getting support for suggested policies, for example by assigning property to the poor, to traditional users, or to important stakeholders. The pressure to establish or clarify property rights, generally, increases as the supply of a given type of property decreases due to resource depletion or increases in pollution even as the demand remains steady or grows. Conditions such as traditional but vaguely documented claims to ownership or free use of land, water, etc., or widespread absentee ownership of land with uncertain tenure for users of the land often lead to overuse of resources and uncontrolled environmental pollution. In addition, as pressure grows on the use of scarce resources the threat of violence among competing claimants, public corruption, and extreme poverty increase. Under these circumstances, clearly defined property rights provide incentives to control pollution impacting the property or to ensure a sustainable use of renewable resources.

The establishment (including definition, granting or allocation), and clarification of property rights include a variety of policies that facilitate improved stewardship of the environment, such as:

- The granting of communal tenure in the use of public property by local communities under conditions that promote sustainable use of natural resources and the reduction of pollution.
- Permanent transfer of tenure rights or ownership from large absentee owners or the government to those who actually farm the land or use the resources. These are sometimes called "*land to the tiller*" programmes.
- Transfer of public enterprises, which have weak incentives to maintain environmental quality, to private individuals or organizations to which strong incentives may be applied.

[15] We do not consider other means of establishing property rights, such as tradition or force of arms.

(Obviously, transfer from public to private ownership without economic or regulatory incentives does little to help the environment.)

For the purpose of this lecture, we examine property right-based instruments under two categories: common property resource management (CPR), and tradeable permits.

(i) Common property resource management (CPR)

In the context of natural resource management in developing economies, common property resource management (CPR) is particularly important. In developing economies, the right to use common property (grazing lands for example) is usually established by tradition, and the resource can be freely used by anyone. Such a system naturally encourages each user to maximize their amount of use. The very act of defining the right to use common property (who, when, how much, under what conditions) creates an economic instrument to manage the use of natural resources and control of the pollution of common property. Using this economic instrument, it becomes possible for the first time to overcome the tragedy of the commons and rationally manage the use of common property. The common property may still belong to everyone in society but the use of it is regulated to prevent abuse. CPR management is particularly relevant when the resources of an ecosystem are erratic, caused, for example, by unreliable rainfall), as well as when there are possible problems, such as the desire of each user to maximize their own use, which will eventually lead to the degradation of community property resources (see Sterner, 2003, Sterner and Coria, 2012 for a review of these conditions)

The literature recognizes three strategies associated with CPR management. These are (i) 'Perfect' government control, (ii) Privatization, and (iii). Cooperative management with local enforcement. The third is considered the superior alternative in many settings. Using such a strategy requires that

- Boundaries are clear and outsiders can be excluded,
- Rules are adapted to site-specific conditions,
- Decision-making is participatory (democratic),
- Locally designated agents monitor resources,
- A local court or other arena is available to resolve conflicts,
- Graduated sanctions are used to punish infringements,
- Outside government respects the CPR institutions

However, there are many potential problems associated with the definition and management of common property rights. For example, lack of trust among the actors can lead to poor results (e.g. when traditional users of grazing lands do not trust government representatives from the capital). In some cases, it may be impossible or difficult to create communal property rights (e.g., in the case of global warming or ozone layer depletion). Further, the creation of property rights may disenfranchise the poor and therefore contributes to worsening poverty (e.g. where, "squatters" or subsistence users lose traditional but informal rights to use property).

(ii) Tradable Permits

The second type of property right is the right to limited use of public assets such as the right to emit pollutants, to take fish from public waters, or graze livestock on public lands. As economic instruments, these property rights take the form of tradable permits.[16] To create a tradable permit system, the government first determines the total amount of a resource to be used or pollutant to be emitted. Thereafter, it issues individual permits to use some part of the total limit, and then, allow the permits to be traded by the holders. For the system to work the total number of permits should not exceed the estimated capacity to assimilate pollutant loads without deteriorating environmental quality, or, in the case of renewable resources, the yield or harvest that can be taken without a decline in the stock size.

The use of tradable permits regulates the total amount of resources that can be extracted or pollution emitted but leaves it to the market to determine who will extract the resources or emit the pollution and at what price. In using this instrument, the decision maker says in effect "in the next ten years, we will only allow a total of X tons of pollutant to be released into the atmosphere" or "for the next ten harvest seasons, the total amount of tilapia to be harvested from Lake Victoria is X tons per season" to be consistent with sustainable management of the environment or the resource base. The government has the option of auctioning the permits, or of distributing them for free ('gifting'). Auctioning will ensure that the market value of the permit is raised by governments. It is often applied when permits are to be given to larger, profit-oriented companies. If issues of poverty are a major concern, or if resistance among participating stakeholders against auctioning is insurmountable, permits can also be given out for free. In both cases, a permit allows its holder to emit a certain amount of pollutant or to harvest a certain amount of a resource in a specified period of time.

After the allocation of permits (through auctioning or free distribution) a firm wishing to emit or harvest beyond what their permits allow can only do so at the expense of another firm. This is possible since it is feasible for a firm to emit less pollutant or harvest less than the permits it holds allow. The permits that are not needed can then be sold to another firm. For example, a firm in a fishery can choose to harvest fewer fish than its allowable quota and sell the extra permits to another firm. For such a scheme to work efficiently, the allocated permits must be transferable

[16] As an economic instrument, this differ from licenses – e.g. for hunting or fishing – which also seek to regulate the total take, in that the licenses cannot be traded and have little associated economic incentives other than the cost of the licenses, which is usually small.

to new as well as existing holders of permits. A permit holder must be able to sell his permits if he or she is making losses and wishes to exit from the market. A new firm that wants to enter the market can only do so by purchasing rights from a firm already operating in the market.

Tradable permits are issued under a number of names depending on the issue to be addressed including:

- Tradable Emission Permits in pollution management
- Individual Transferable Quotas in fisheries management
- Transferable Grazing Rights in range management
- Transferable Development Rights in property management.

The most successful permit-trading programmes have included

- **Emission Reduction Credit Programmes**: where a firm that reduces emissions more than required gets credit for the extra reduction, which the firm can either sell to firms whose emissions are above the statutory maximum, or can bank for its own later use.
- **Ambient Permit Trading**: A variant of tradable emission permits in which the value of emission reduction credits differs from region to region depending on the relative ambient concentrations so as to discourage development of 'hot spots'.
- **Output Based Allocation**: This is used for the initial allocation of pollution permits, based on relative output levels of existing firms.
- **Cap and Trade Programmes**

However, several conceptual and practical problems must be overcome in the application of tradable permits. First, for the permits or quotas to work, they must acquire the characteristics of other property rights, such as permanence and reliability. Permanency gives owners of property rights the confidence and incentive to make long term and costly productive investments in their properties. If permits or quotas are not seen as a real title for property, the market for them will not develop, and without a market their worth as an economic instrument is nil.

Second, the potential buyers of permits need to understand the market. This may require considerable public education. In the case of natural resource management, a lack of knowledge among users of the resource about the underlying ecosystems and lack of agreement about how they should be managed can create major difficulties. Policy makers need to ensure that all stakeholders have a common agreement about the essential facts and trust in the research that produced them.

Third, many features of permit systems (i.e. the definition, number, duration, and temporal and spatial validity of the permits and the proposed method of their allocation) cannot be decided using only ecological and technical calculations. At bottom, these become political decisions. These decisions are crucial for the performance of the programme but can entail immense political pressure because permits transfer valuable property rights and, potentially, substantial wealth.

Finally, there is the problem of *thin markets* and transaction costs. Thin market exists If a permit system is established but very few people are willing to trade in it. In this case, the market will not develop properly. The same will be true if traders of permits incur high transaction costs, for example, if the trading process is lengthy and complicated or involves fees. Designers of tradable permit systems need to make sure that the permit market is sufficiently big to allow for multiple trades, and they need to find ways to keep transaction costs low. In addition, for tradable permits to work properly, prescribed targets for total use of emissions must be responsive to changes as the operating environment changes, for example as abatement technology improves. For instance, if a standard abatement technology commonly used by all companies used to have 60 per cent efficiency in eliminating pollutants but now has 80 per cent efficiency. This means that most firms would have extra credits to sell or bank leaving few potential buyers and little incentive to reduce pollution. In such a situation, the total permitted pollutants would need to be reduced again creating the scarcity required for a market to work.

4.1.3.3 Legal, Voluntary and Information-Based Instruments

Legal instruments hold individuals and organizations liable for environmental damage they cause. They include criminal penalties, fines, civil liability statues, and performance bonds. Voluntary and information-based instruments include voluntary environmental agreements, information campaigns, eco-labelling, and other certification.

(i) Legal Instruments

Legal instruments are designed to ensure the enforcement of rules by increasing the economic cost of non-compliance. These economic penalties remove the competitive advantage that the firm would gain through non-compliance. Most enforcement relies on three types of legal instruments imposing economic penalties: fines, liability and performance bonds.

- **Fines:** fines are commonly imposed by the government when a firm has knowingly violated environmental or health laws to make a profit. Fines are relatively easy to impose and can often be assessed on the spot. In some cases, special administrative procedures and courts are established to allow more efficient use of fines as an economic instrument. The use of fines to ensure compliance, however, requires that the government has sufficient police or inspectors, appropriate legal staff, and a functioning legal system. From an economic perspective, the penalty imposed by fines must be large enough to actually deter undesirable behaviour. Small fines may be seen as merely a cost of doing business. Not only the amount of the fine itself is important, but also the probability of being caught when violating an environmental law. Companies will have an economic incentive if their expected cost from a violation, namely the probability of being caught multiplied with the level of the fine, is higher than the benefit they expect from bypassing the rules.

- **Liability:** Under liability sanctions, an accused violator may be taken to court – by either the government or private plaintiffs - to compensate for the cost of environmental damage. Liability sanctions are usually easier to enforce and much more costly to the violator than are fines. They do, however, require a fully functioning legal system and, even then, may involve prolonged litigation. Companies could be strictly or partially liable for damages caused and this may have important implications for their behaviour. Partial liability implies that the person injured has the right to compensation only if the party causing the injury has taken less than due precautions. Strict liability means a right to compensation irrespective of precautions. Suing a large firm or government agency is risky and expensive, and many individuals do not have the necessary resources to hire a lawyer and proceed with a lawsuit. The incentive to do this is further reduced in the case of partial liability. Strict liability gives more rights to the injured individuals and can be seen as the ultimate policy instrument that promotes the internalization of all environmental damages and risks.

- **Performance Bonds.** Governments often require that firms have special insurance, known as a performance bond, to ensure that they have the wherewithal to actually pay for the environmental damages they cause. An economic deterrent effect for potential violators is the increased cost for future performance bond insurance – or the inability to obtain such insurance at all - if the firm needs to use the insurance to cover environmental damage liabilities. In addition, firms will not be able to purchase performance bonds if bonding companies deem them likely to violate environmental regulations in the future.

  Performance bonds have the advantage that they make it relatively certain that governments or private plaintiffs can recover damages. The fact that insurers are assessing the risks of non-compliance increases the effectiveness of environmental policies. However, the use of performance bonds is usually restricted to industries with a greater than average risk of causing significant environmental damage – oil transport, forestry, mining, heavy industry – where the additional cost of the bond insurance is commensurate with the risk.

The empirical application of legal instruments may be difficult in those developing countries where the judicial systems are weak. Specific problems with the use of legal instruments include the very high costs of litigation, lack of information about liability, and poorly or incompletely defined property rights making responsibility for damages uncertain and the imposition of penalties impossible.

(ii) Voluntary Environmental Agreements

Voluntary environmental agreements are agreements among private firms, government agencies, and/or nongovernmental organizations designed to encourage voluntarily investment, clean-up, or other changes to reduce negative environmental impacts. The incentives for such agreements include subsidies, favours, positive publicity or good relationship with the government. In recent years, 'voluntary agreement' has become a popular catchphrase among environmental policy experts and are promoted as a useful instrument for policy making. For example, more than 13,000 US firms, nongovernmental organizations and local agencies were estimated to be involved in voluntary government initiatives in 2000 (US Government, 1998, see UNEP, 2009). To serve as an economic instrument, the agreement needs to produce a level of abatement beyond the one achieved without government involvement. For these reasons, voluntary agreements are often organized and facilitated by the government rather than arising from within the regulated industries.

Under voluntary agreements, firms agree to invest, clean up, or undergo changes to reduce negative environmental effects and receive, in exchange, subsidies or other benefits. The benefits may take the form of more lenient regulation, some official protection against civil liability lawsuits, good publicity, a good relationship with the government, and perhaps speedier and less formal treatment of other environmental controls. In developing agreements, the government agency may negotiate an agreement with a single firm (especially if it is a large firm with a major impact on the environment) or with multiple firms represented by a trade association or other intermediary organizations.

The relative benefit of voluntary agreements over command and control instruments or the more measurable benefits of most economic instruments may be as much a cultural or a psychological one as one of effect. It has been suggested that the 'covenanting process'—that is, the dialogue itself, rather than the formal agreement—has been touted as the main feature that makes voluntary agreements successful. Voluntary agreements allow firms to save face before their stockholders while accepting the fact that they must spend company funds to reduce emissions or curtail exploitation of natural resources. In the same way, voluntary agreements allow the government regulatory agency to improve its image with the public, elected officials and the general business community by presenting itself as open-minded and reasonable in its dealings with the private sector rather than inflexibly bureaucratic. They are also sure that firms are more likely to comply with the measures to which they agreed. Thus, the agency can get some savings in regulatory costs.

Voluntary agreements are popular in cases where firms are in some way rewarded for engaging in more abatement than would normally be required. They are most promising when the opportunity for technical abatement is good while imperfections (in the product or technology markets) make the use of conventional instruments, such as taxes, difficult. In addition, voluntary agreements are an alternative to taxes when emissions verification is problematic. From the government perspective, voluntary agreements may be most attractive in cases where the government does not have sufficient power to coerce the polluter. In contrast, firms may be more inclined to voluntary agreements when the state has sufficient power to enforce its will without an agreement, because then, firms will be motivated to negotiate the best conditions possible.

One potential problem with voluntary agreements is that they depend on other tougher instruments to function. Strong environmental lobbies that stimulate firms to acquire 'green' labels, and therefore enter into voluntary agreements, are often lacking in developing countries. Thus, the potential for voluntary agreements in such countries appears to be weak. The voluntary banning of chlorine from paper bleaching in Sweden illustrates the notion that voluntary agreements work best against a backdrop of tougher instruments. The companies stopped using chlorine, although their response was a reaction to plans to introduce an environmental tax on chlorine. Presumably, the demand for 'green' labels on paper products also contributed to this shift. As the Swedish government and parliament were drafting the laws, industry decided to be a 'first mover' and voluntarily ban chlorine. In this way, they avoided the tax payment, gained good publicity, and set a precedent for future battles concerning environmental legislation (See Sterner, 2003. pp 119-122 on and more on the potential and scope of voluntary agreements for enhanced environmental management).

(iii) Information-Based Instruments

All policy instruments require information to function, but public disclosure of information can be an economic instrument in its own right. As an economic instrument, public disclosure can change environmental behaviour of polluters and consumers by directly influencing the market. The instrument is used to publicize those firms or products that meet certain standards in the way they are produced or harvested.

Information-based instruments are becoming increasingly popular among theorists and in real world applications. Information provision has been referred to as the 'third wave' of environmental policy making (presumably after command and control instruments and economic instruments), and its popularity can be explained by the changing costs of providing, processing and disseminating relevant information. Information disclosure as an instrument for pollution management is particularly promising in situations where administrative costs of more traditional policies are excessive (see Sterner, 2003, pp 122-126, for applications in northern Europe). In addition, there is growing acceptance of public disclosure for natural resources management in both industrialized and less developed countries (e.g., organic farming, forest certification programmes).

Forms of information disclosure include:

- **Labelling:** where products are directly labelled as being environmentally friendly or meeting certain criteria (e.g. low energy usage, organic).
- **Public Disclosure:** in which comparative information about the environmental practices or violations of environmental law of different companies is made available to the public. Product by product comparison can also be provided.
- **Ratings** or **Rankings** : provide information about the environmental impact of a product or the environmental performance of a firm on the relative scale (e.g. Grade 1, 2, or 3). The advent of the internet has made such information easy to access and increasingly powerful.
- **Environmental certification of firms:** which use a fixed system of certification within some predetermined bounds such as ISO 14000 or EMAS standards[17]. These systems are usually oriented towards the management structures of firms, and not towards compliance with environmental standards or environmental performance per se.

Disclosure programmes may also be categorized by the item certified (the target): they can provide information about products, the firms themselves, or their processes and management procedures. Product labelling programmes have been around for decades and the number of product labelling programmes has been increasing rapidly. Examples include 'Organic' certification of food, which is widespread, and probably one of the oldest programmes; Type 1 'green' labelling of products, which has become popular in northern Europe; Certification programmes, such as the Canadian Environmental Choice, the US Green Seal, the Japanese ECO MARK, and the French NF Environment (UNEP, 2009).

Some potential problems with the use of Information-Based Instruments include the fact that low-income levels in developing countries may prevent the majority of people from being able to make consumer choices, which are necessary for information-based instruments to be effective. In addition, agents may use 'green' and 'eco' labels as mere mantras without necessarily adequately protecting the environment. One area where this seems to be prevalent is in 'eco-tourism'. Finally, there may be inadequate knowledge or concern about the advantages of green products.

[17] EMAS: Eco-Management and Audit Scheme of the European Union. ISO 14000: International Standards Organization rules for environmental practices (for more information see http://europa.eu.int/comm/environment/emas/index_en.htm and http://www.iso.org/iso/en/iso9000-14000/index. html.

4.1.4 Direct Provision of Public Goods

The purpose of the direct provision of public goods is to maintain environmental or natural resource quality through direct public expenditure. In this case, the government (through its environmental protection agency) takes direct responsibility for solving a particular environmental or natural resource management problem for which the market cannot successfully provide a universal solution. Examples include:

- Street cleaning
- Disease vector (e.g. mosquito) control (taking responsibility for major environmental threats and managing certain kinds of research and control functions typically undertaken by environmental protection agencies)
- Maintenance of urban water and sewer systems (although the state or municipality usually tries to cover costs by charging some kind of user fees. Such fees may be part of property taxes or other taxes, or, as is becoming increasingly common, they may be user fees tied more specifically to the service provided).
- Maintenance of natural parks and nature preserves

Under direct provision, a resource or environmental ministry applies its own personnel, know-how, and resources to solve a given problem. In the environmental arena, this mechanism is essentially the provision of public goods.[18] These activities, of course, can also be carried out by private companies but only at the behest of the government or quasi-government organization (e.g. a homeowners' association), which becomes the sole customer for the service.

For example, the creation of parks and protected areas that exclude livelihood activities is a common approach to protecting biodiversity. Protected areas have strictly defined borders that unauthorized people are not supposed to cross. Marine protected areas are a somewhat more recent addition to the plethora of land-based parks. In some cases, they are designed specifically to protect a stock. Certainly, this policy will work best if the area chosen truly does create services that are of value for other areas in the neighborhood that are still being fished.

However, direct government provision of environmental services is susceptible to the usual problems that confront the provision of public goods. In particular, because the government is providing a public good, it is likely to under supply, more so in countries with weak governance structures and low tax bases. Also, free provision of some public goods such as fresh water will result in overuse by consumers and can lead to exploitation of valuable resources. In addition, since provision of public goods is often done by political agents allocating public tax money to specific projects, politicians may seek to expand the definition of public goods to subsidize particular constituencies. In addition, political access and power influences which of the many

[18] Some will argue that the phrase 'policy instrument' is not appropriate in this context and will rather reserve the word 'instruments' or policies that influence other agents (Coria and Sterner, 2011),

possible projects get funded, and how quickly. The projects of greatest need from a social or environmental point of view may differ markedly from those with the strongest political constituencies or greatest political return for the public official.

The role of the state can be broken down into several components: financing, administration, provision, and control. During the two to three decades, in most countries, the state has started to refrain from acting as direct producer of goods and services, focusing instead on financing. Several activities that were formerly thought of as natural state monopolies have been organized in such a way that the government agency merely retains a control function, and private entrepreneurs are hired to provide the services. One of the factors that have contributed to this change is the remarkably negative popular image of state enterprises as incompetent elephants beyond the control of the government. Nevertheless, state resource enterprises are still very common, partially due to the strategic nature of many natural resources and rent-seeking opportunities that permit government officials to gain the political support from key actors outside the government.

For exploitation rates to be sustainable and dynamically efficient, government must ensure that state enterprises are kept accountable for the quality of their resource management and the damages they cause. Governments must also ensure that directives to state resource enterprises call for appropriate rates and methods of resource exploitation. Unfortunately, this is not often the case. Instead, governments fail to keep state resource managers accountable, demand that state enterprises engage in over or under-exploitation of resources, make inappropriate investments within and outside the resource-exploitation process or set the prices of state-produced outputs too high or too low. Undercapitalization of state enterprises is also common, due to the government's unwillingness to approve adequate investment budgets, its excessive taxation of state operations or the failure to prevent that funds are diverted away from needed investments (Ascher 1999, see Coria and Sterner, 2011).

Table 4.2 helps to sum up our discussions on environmental and natural resource policies.

Table 4.2: A taxonomy of policy instruments

Policy Instrument	Some applications to natural resource management
I. Command-and-Control (Environmental Regulations)	
Detailed Regulation **-**Regulation of technology (designation of technology, zoning) -Regulation of performance Legal mechanisms, liability	Automobile emission control, regulation of nuclear power, zoning regulation of fishing (e.g., dates and equipment) Bans on ivory trade to protect biodiversity, bans on use of cyanide and dynamite in fishing, ban of certain pest control techniques in agriculture and forestry, Water quality standards Harvesting and replanting rules in forestry. Liability bonds for mining or hazardous wastes
II. Economic Instruments	
1. Price-based instruments (Using Markets) Taxes, fees, or charges Subsidies and subsidy reduction Deposit refund schemes	Mining royalties, Gasoline taxes, vehicle weight charges, user fees, land charges, Park fees Fishing licenses Stumpage fees Reduced agricultural subsidies Reforestation deposits or performance bonds in forestry
2. Property rights-based Instruments (Creating Markets) Creation of property rights Common Property Resources Tradable quotas or rights	Private national parks Property rights and deforestation CPR management Water trading, individually-tradable fishing quotas, Transferable rights for land development, forestry, or agriculture, rights to emit pollutants, to take fish from public waters, or graze livestock on public lands
3. Legal and Voluntary-based Instruments (**Engaging the public**) Information Provision, Labels Voluntary Agreements	fines, civil liability statues, and performance bonds green labeling of food, forest products, public disclosures, ratings and rankings, environmental certification (organic' certification of food,
III. **Direct provision**	Direct provision of parks

Source: Adapted from UNEP (2009) and Coria and Sterner (2011). p20.

4.1.5 Second-best mix of policies

In Module 2.4 we learnt that second-best policies are called for whenever there are cases of multiple market failures and that this is especially often the case in relation to environmental and natural resource problems. Several other daunting challenges come into play, including the need to

- consider not only efficiency but feasibility and in particular distributional concerns in policy selection
- deal with combinations of goals. Environmental problems are urgent but so are many other pressing goals such as dramatically urgent needs for poverty alleviation, employment creation, or conflict resolution;
- deal with policies that require action at the local, national, and international levels.

Sound realistic policy-making must deal with ways these policies interact. This will often require a form of second-best policy mix (Damon and Sterner, 2012).

There is a growing emphasis on political feasibility in the design of appropriate policy instruments to address environmental and natural resource problems. This is even more relevant in the context of developing countries, and in the case of Sub-Saharan Africa. Experience with market-based environmental policies has deepened over the past two-to-three decades, so has the ability to adapt policy instruments to complicated and heterogeneous contexts. However, not much progress has been made in meaningfully accounting for the importance of political feasibility (political realities and contextual nuances) in the choice, success or failure of environmental and natural resource management policies. Political feasibility often hinges on factors, such as risks to competitiveness and employment, or on the distribution of costs of certain policies rather than on considerations of pure efficiency alone (Damon and Sterner, 2012).

Expectedly, the central role of policy instruments goes beyond efficiency to achieving a just and sustainable development. The goal of green growth cannot be achieved without sound policies that are both effective and politically realistic. Many believe an emerging understanding of the interaction between policy instruments and the political landscapes in which they must be adopted, should be harnessed to drive the next stage of green development. As aptly stated, 'policy making does not happen in a vacuum' and the study of environmental policy choices must start to holistically incorporate the ways that instruments interact with other political goals—if there is hope of these instruments being adopted widely and designed effectively (Zivin and Damon, in Damon and Sterner, 2012). Honlonkou and Hassan (2014)[19], argues for example, that

[19] Honlonkou and Hassan (2014), Designing Environmental Instruments to Finance Agricultural Intensification Through the Clean Development Mechanism: Direct Cost Subsidy Versus Tax Cut Under Asymmetric Information, Springer International Publishing Switzerland, September 2014 DOI: 10.1007/978-3-319-09360-4_28

one of the most successful instruments so far to address climate change, the Clean Development Mechanism (CDM) is at pains to succeed in small, developing countries facing sustainable development problems like food security. Worse, while the CDM succeeded in financing agricultural projects, few are funded in small, developing countries. For many countries in Sub-Saharan, solving poverty problems may predominate over solving pollution problems if a choice exists between the two (Rowland, 1973).

Summary

- For the government to address a given natural resource management or environmental problem, it must find and use the appropriate policy tool. The policies available to redress environmental problems fit into two broad classes: command and control instruments and economic instruments.

- Command and Control Instruments are the laws and regulation used by governments to directly control pollution and manage natural resources. In the application of these instruments, the government stipulates the technologies that must be used to curb pollution, determines the maximum amount of emissions that is permissible, and regulates the use of natural resources.

- Economic instruments provide market and financial incentives for polluters and natural resource users to change their behaviour by making pollution and overuse of natural resources more costly.

- Both command and control and economic instruments attempt to shift the costs and responsibilities associated with pollution or over exploitation back to the polluter or user. The differences between the two policy types, however, are significant in terms of cost and effectiveness.

- Command and control (CAC) policies for environmental regulation include those that regulate technology and those that regulate performance

- Where appropriate, technology regulation can provide clarity of choice, economy of administration, effective control, and ease of monitoring. However, a major drawback of technology regulation is its inflexibility.

- Performance regulation targets individual levels of emissions or natural resource exploitation by imposing directly-enforced government limits on the quantity of emissions or harvest of a renewable resource for each individual or firm. Options in this category includes performance standards, tradable emissions permits, and zero emissions.

- A potential problem with performance regulation is that controlling individual emissions rates do not imply full control on total levels of pollution or ambient pollution levels since total pollution levels depend both on the output for each agent and the number of agents operating in the economy.

- Economic instruments provide financial incentives for polluters and natural resource users to reduce output of pollutants and unsustainable use of natural resources. They include price-based instruments, property rights-based Instruments, and legal, voluntary and information-based instruments.

- Price-Based Instruments include special government taxes, charges, or fees designed to raise the price of polluting the environment or exploiting natural resources. Common price-based instruments are direct taxation, input and output taxation, emission or access charges, refunded emissions payments, deposit refunds, subsidies and removal of perverse subsidies.

- Property Rights Based Instruments define, adjust, or create property rights to ameliorate environmental damage by defining the basic enforceable law for ownership and use of both tangible (e.g. land) and intangible (e.g. permits) property. The purpose is to manage the environmental assets by creating, clarifying, and enforcing rights to specific property. They include common property resource (CPR) management, and tradeable permits.

- Common property resource management CPR management schemes include 'Perfect' government control, Privatization, and Cooperative management with local enforcement. The third is considered the superior alternative in many settings.

- There are many potential problems associated with the definition and management of common property rights. For example, lack of trust among the actors can lead to poor results (e.g. when traditional users of grazing lands do not trust government representatives from the capital). In some cases, it may be impossible or difficult to create communal property rights (e.g., in the case of global warming or ozone layer depletion). Further, the creation of property rights may disenfranchise the poor and therefore contributes to worsening poverty (e.g. where, "squatters" or subsistence users lose traditional but informal rights to use property).

- Tradable Permits confers the right to limited use of public assets such as the right to emit pollutants, to take fish from public waters, or graze livestock on public lands. The use of tradable permits regulates the total amount of resources that can be extracted or pollution emitted but leaves it to the market to determine who will extract the resources or emit the pollution and at what price. However, several conceptual and practical problems must be overcome in the application of tradable permit, such as permanence and reliability, the need for potential buyer to understand the market, and political considerations.

- Legal instruments hold individuals and organizations liable for environmental damage they cause. They include criminal penalties, fines, civil liability statues, and performance bonds. Voluntary and information-based instruments include voluntary environmental agreements, information campaigns, eco-labelling, and other certification.

- Legal instruments are designed to ensure the enforcement of rules by increasing the economic cost of non-compliance. These economic penalties remove the competitive advantage that the firm would gain through non-compliance. Most enforcement relies on three types of legal instruments imposing economic penalties: fines, liability and performance bonds

- Voluntary environmental agreements are agreements among private firms, government agencies, and/or nongovernmental organizations designed to encourage voluntarily investment, clean-up, or other changes to reduce negative environmental impacts. The incentives for such agreements include subsidies, favours, positive publicity or good relationship with the government.

- There are many forms of information disclosure including labelling **(**where products are directly labelled as being environmentally friendly or meeting certain criteria, e.g. low energy usage, organic), Public Disclosure **(**in which comparative information about the environmental practices or violations of environmental law of different companies is made available to the public), Ratings or Rankings, which provide information about the environmental impact of a product or the environmental performance of a firm.

- Some potential problems with the use of Information-Based Instruments include the fact that low-income levels in developing countries may prevent the majority of people from being able to make consumer choices, which are necessary for information-based instruments to be effective. In addition, agents may use 'green' and 'eco' labels as mere mantras without necessarily adequately protecting the environment. One area where this seems to be prevalent is in 'eco-tourism'. There may also be inadequate knowledge or concern about the advantages of green products.

- The purpose of the direct provision of public goods as an instrument is to maintain environmental or natural resource quality through direct public expenditure. In this case, the government (through its environmental protection agency) takes direct responsibility for solving a particular environmental or natural resource management problem for which the market cannot successfully provide a universal solution.

- In general, economic instruments possess a number of inherent advantages over command and control instruments for many problems. They are generally more affordable, flexible, responsive, and encouraging to technology innovation. In addition, although economic instruments cannot overcome a corrupt or weak political structure, they can help make moderately functioning governance structures work more effectively. As such they try to minimize possible policy and institutional failures.

- In practice, economic instruments are used together with command and control instruments to increase policy efficiency, and achieve environmental targets at a lower cost.

Discussion Questions

1. Consider the following case studies

Case 1: Reforestation effort in Brazil

In an effort to encourage good reforestation practices, timber policies in Brazil charge a tax on wood consumption except when the harvesting is offset by equivalent reforestation. Recognizing that there are insufficient resources to oversee reforestation directly, Brazil has chosen to forego revenues from timber sales so long as the cuts are properly replanted. However, the programme has generally failed. The tax on wood consumption is set too low to make it worthwhile for the foresters to replant. In any event, the programme is poorly enforced so that foresters rarely pay the tax at all. Monitoring is difficult especially in frontier regions. Those forestry fees that were collected usually go to pay administrative costs rather than support the environmental purposes for which they had originally been intended (Source: UNEP, 2004. Also in UNEP, 2009).

Case 2: Soil conservation in Dominican Republic

In the El Naranjal watershed in the Dominican Republic, US AID funds provided subsidized credit to participating farmers adopting soil conservation measures. Initial adoption rates were quite high (90 per cent in 1985), yet by 1990, only half of the farms continued to practice the conservation measures, as the subsidies had stopped. As further subsidies were expected, farmers actually delayed rational conservation measures in order to wait for the payment. The follow-on project of US AID recognized that the farms were already receiving tremendous benefits in the form of subsidized irrigation water. This second project tied continued access to subsidized water to proper adoption of soil conservation measures. The result has been substantial use of conservation techniques without additional direct subsidies. (Source: UNEP, 2004; UNEP 2009).

For each of these cases, what can you identify as the problem and/or solution. What lessons can be learnt for effective formulation of environmental policies?

2. The case study below is used to illustrate, among other things, that 'no environmental programme - even when using highly effective economic instruments - is ever really finished'

(a) Read through and state whether you agree or disagree and why?

(b) What lessons can we learn on how property rights measures can be used to address difficult environmental issues.

Case 3- Tenure Reform: Mankote Mangrove, St. Lucia

A common property rights economic instrument proved ideal in the efficient management and sustainability of the Mankote mangrove forest ecosystem in the Caribbean nation of St. Lucia. The Mankote forest comprises the largest contiguous tract of mangrove in St. Lucia and 20 per cent of the total mangrove area in the country. The government had traditionally prohibited exploitation of the publicly owned forest but allowed open access. The prohibitions proved ineffective. Widespread and uncontrolled charcoal harvesting threatened to destroy the entire forest. The imminent destruction of the forest, in turn, greatly endangered the many ecosystem services the mangrove forest provides, including maintaining coastal stability, preserving water quality, serving as a fish breeding and nursery ground, trapping silt, and providing an important bird habitat.

Most of the charcoal was harvested by extremely poor subsistence harvesters who had no legal right to any use of the publicly owned mangrove resources. The harvesters had no ready alternative employment should their access to the mangroves be cut off due to either resource depletion or effective policing. To protect the mangrove as both an ecological and economic resource, the government organized the subsistence users into a collective and granted clearly defined communal tenure rights for charcoal extraction. For the first time, the harvesters had a direct stake in the sustainability of Mankote resources. Communal tenure also gave each individual harvester an incentive to monitor his peers and ensure mangrove cutting regimes were properly followed. Technical training on effective ways to manage cuts was provided, as well as periodic monitoring of the overall mangrove health (as measured by tree size and number of new stems). Longer-term efforts to reduce the economic pressure on the mangrove were implemented using job training programmes and the attempted development of a hardwood forest outside of the mangrove. (This last element has been of limited success). As part of the programme, Mankote was established as nature reserve. Thus, not only did the programme secure the tenure of the charcoal harvesters, it worked successfully to prevent threats to the Mangrove from large-scale development or fishing.

By modifying property rights, St. Lucia (in large part due to efforts of the Caribbean Natural Resources Institute, a regional NGO) has been able to protect the Mankote Forest and all its ecosystem services. Mangrove depletion has stopped and tree cover is now increasing, all without displacing jobs. Despite the overall success, the case does have some problems that should serve as a caution to users of this model: The process has taken more than 15 years. Many resources at risk elsewhere would not survive such a long policy gestation period. The harvesters' tenure may not be secure. The tenure is granted through a letter from the Deputy Chief Fisheries Officer; it is not clear how much legal protection such a letter provides. Threats from outside developers remain, and challenging the validity of the tenure rights would seem an obvious tactic. Intensive development at the borders of Mankote could fragment ecosystems sufficiently to reduce the viability of the area. Finally, there is little information on how the new tenure holders will constrain internal growth of their group to ensure harvest pressures remain sustainable. (**Source:** UNEP, 2009).

3. Read the following case study and discuss the questions below individually or in groups.

(a) What is/are the environmental problem(s) described in the case study?

(b) What are the baseline conditions in the country (legal, fiscal, government)?

(c) What is / are the economic instrument(s) chosen? What is / are its / their objective(s)?

(d) Who are the main stakeholders involved?

(e) What are the main factors for success or failure?

(f) What message can you take for your own country case?

Case 4: Recovering Reasonable Fees from Resource Users

The public sector invests hundreds of millions of dollars to bring services to the populace of many developing countries: electricity, drinking water, and wastewater treatment are examples. Similarly, government owned natural resources comprise an asset of the state, owned by its citizens. There are strong arguments to be made for supporting cost recovery from beneficiaries for both consumptive (e.g., harvesting firewood, grazing) and non-consumptive (e.g., recreation) use. Despite the logic behind cost recovery, there is a widely held belief that many of these municipal services should be free. Here is an example from Country C.

Pasture Lease Agreements (PLAs) for ranchers to graze cattle on public lands have existed for decades in Country C. The lease terms last 25 years, and is renewable for another 25. Grazing fees were first imposed in 1961 through Administrative Order 08 at an average rate of less than

US $0.01/hectare per year. An initial fee increase was authorized in the Forest Land Grazing Lease Agreement of 1982. Fees were raised again in 1991 to the current rate of US $0.30.

Compliance with the fees has generally been quite high given the still very low rate. The low rates also led to a relatively small group of people gaining control over much of the public grasslands for the 50-year lease period. The ability to shift cattle to new pastures they control has also reduced the incentive for sound management of the pastureland, and led to land degradation in many parts of the country.

Although existing rules require ranches to file annual operating plans as well as a management plan every eight years, the Department of Environment and Natural Resources (DENR) has lacked resources to oversee management plans. This is the result of insufficient funding as well as difficult terrain to oversee. To address the problem, DENR's Ecosystems Research Development Board (ERDB) evaluated what the true economic rent should be, accounting for the cost of various measures to rehabilitate existing damages, and the economics of alternative land uses. While more than 10 times higher than the prior charge, the new rates were still believed to be only slightly more than half the lowest economically justifiable rent on the land. In addition, the charge had a five-year phase-in period. To support the transition, the policy included increased technical assistance as well as fee reductions for sound land management. Rights have continued with existing holders, with the price of those rights (through an annual rental fee) set by statute. The fee adjustment was authorized by Department Administrative Order 2001-05, which took effect in August 2001.

Despite some evidence that even this fee was still low, and the fact that 80 per cent of the surcharge could be used to correct existing damage on the grassland the ranchers have fiercely resisted the increase. A number have refused to pay the higher rates, a situation the DENR had not been prepared for. There had been a series of public hearings run by ERDB to discuss existing and proposed grazing fees. Ranchers were already well organized as a stakeholder group, and strongly opposed rate increases. They argued that the government should view their presence on the land as a benefit in that it curbed squatting by migrants. They also mobilized strong political actions against the ERDB and DENR to oppose the rate increases.

As a result, DENR ended up collecting nothing from them mainly due to its little capability to carry out full enforcement. Furthermore, during a trip to the region in early 2002, a top government official promised to reduce the fee substantially "to encourage breeding and create 60,000 jobs". This statement undermined current efforts to collect the higher fees, and led DENR to suspend its collection pending formal clarification on how to proceed. DENR has been unable to overcome local political opposition. As a result, the grasslands remain under great threat, and additional resources that the higher fees would have brought in are not available to stem the damage. Existing ranching practices are unsustainable, and current regulations on management reporting and planning by ranchers are not enforced. As a result, ranchers continue to have low cost, long-term access to public grazing lands with little incentive for proper land management.

In the face of such opposition regarding fee levels and enforcement, auctioning of rights could have offered a substitute for a user fee. Although auctions will not work for cost recovery on government owned or built infrastructure, they can be very helpful for applications where there is little fixed infrastructure and the users can be quickly changed.

Individual/Group Assignment/Term paper

1. Examine and evaluate forest management reform in Botswana/your country.

2. Examine and evaluate Wildlife User Rights and Wildlife conservation in Zimbabwe/your country

3. Provide a case study of a successful/an unsuccessful common property resource (CPR) management system in your country

4. Evaluate the consensus on the UNEP report on Ogoniland, Nigeria.

5. Evaluate progress on Eco-tourism in Kenya

6. Explain the factors militating against the effective use of legal, Voluntary and Information-Based Instruments in Sub-Saharan Africa

7. Evaluate initiatives to regulate the use of plastic bags in Sub-Sharan Africa

8. Why is it that tradeable permits may not be as effective in Sub-Saharan Africa in addressing environmental problems as it would be in developed countries?

Exercise

1. Consider an industry that produces electricity from coal. A REP system is being considered that would involve imposing a tax per unit of carbon dioxide emitted by firms in the industry. The money would then be returned to the power plants according to their share of output of electricity. Use the knowledge gained from this lecture to assess the proposed policy.

Materials used for this Module

4. Coria and Sterner (2012). Natural Resource Management: Challenges and Policy Options, Annual Review of Resource Economics DOI: 10.1146/annurev-resource-083110-120131

5. Damon, M and Sterner, T. (2012) Policy Instruments for Sustainable Development at Rio +20, *Journal of Environment & Development* 21(2) 143–151. DOI: 10.1177/1070496512444735

6. UNEP (2009): The Use of Economic Instruments for Environmental and Natural Resource Management First Edition.

7. Titenberg, T. & Lewis, L. (2012). Environmental & Natural Resource Economics 9th Edition, The Pearson Series in Economics

8. Sterner, T. and J. Coria (2012). Policy Instruments for Environmental and Natural Resource Management. Resources for the Future.

Module 4.3: Evaluating Policy Instruments (5.5 hours)

Learning Outcome

This Module describe how to choose between and evaluate various policy options to address environmental problems. By the end of the module, you should be able to

- ✓ Identify the various steps involved in choosing an effective environmental policy package to address a target environmental problem
- ✓ Understand the importance of the policy environment and baseline conditions
- ✓ Know the factors that should guide policymakers in the choice of the most appropriate policy option for a given problem and why context matters.
- ✓ Know some basic criteria for evaluating environmental policies.
- ✓ Understand cost-effectiveness criterion and know how to apply it to different types of pollution problems.
- ✓ Understand why market-based policy instruments are often preferred to command-and-Control Instruments.
- ✓ Appreciate the importance of political feasibility, social and distributional considerations in choosing policy instruments.

Content Outline

4.3.1 Choosing an effective environmental policy package to address a target environmental problem

4.3.1.1 Introduction

4.3.1.2 Understanding the nature and extent of the problem and determining baseline conditions

4.3.1.3. Making Policy Choices

8.2.2 Evaluation Criteria

4.3.2.1 Introduction

4.3.2.2. Cost-Effective Policies for Uniformly-Mixed Fund Pollutants

4.3.2.3 Cost-effective Policy for Nonuniformly-mixed Pollutants

4.3.2.4. Cost-effectiveness and Renewable Resources

4.3.2.5 Beyond cost-effectiveness: Political feasibility, social and distributional Issues

Summary

Discussion Questions/Case studies

Exercises

Materials used for the Lecture

4.3.1 Choosing an effective environmental policy package to address a target environmental problem

4.3.1.1 Introduction

While an understanding of the theoretical benefits of particular economic instruments can be useful, the existing institutional capabilities and environmental policies in the country need to be taken into account in the choice of an effective environmental policy package that will address a given environmental problem. Practical consideration of the status quo in a country, including institutional strength, existing policies, and stakeholder power dynamics, will have enormous influence in deciding the most viable policy approach.

Policy choice and implementation generally encompasses four main phases.

- **Phase 1: Conducting Policy Analysis**. This entails a careful analysis of the perceived problem, a review of the instruments available to address the problem, the conditions under which these instruments will be used, and the likely effect of various instruments or combinations of instruments on the problem. This phase is usually concluded with the drafting of initial policy recommendations.
- **Phase 2: Engaging Stakeholders.** This involves bringing in stakeholders for feedback on initial policy recommendations and collecting important information on how to refine these to increase their likelihood of success or to gauge any major resistance. This input is then fed back into the information bank developed in Phase 1.
- **Phase 3: Finalizing Policy.** This phase takes the general information assembled in Phase 1 and 2 and uses it to develop final policy proposals.
- **Phase 4: Implementing and Evaluating**. This involves gaining political support, passage of any necessary legislation, establishing regulations, and establishing administrative, monitoring, enforcement, and evaluation procedures. Once legislation is enacted a strict timeline for implementing the chosen policy package should be prepared. Similarly, additional work on any measures needed to assess impacts of the change on poverty, the environment or other variables of interest may also be required (see UNEP for detailed discussion).

4.3.1.2 Understanding the nature and extent of the problem and determining baseline conditions

Deciding on the most appropriate instruments to address an environmental challenge requires that policymakers must first determine the nature and extent of the problem. What is, for instance, the:

(i) Nature of the problem: overuse of a resource or a pollutant problem?

(ii) Potential effect on human welfare and the environment, including the nature of the problem over time. (The passage of time becomes important if one is interested in a pollutant that bio-accumulates in the environment or if a natural resource is irreversibly degraded.)

(iii) Geographical reach of the affected area. Is the problem a local or regional problem?

(iv) Vertical dimension of the pollutant. Are the effects felt on the surface or in the upper reaches of the atmosphere?

(v) Number of people involved. (The damage a pollutant causes depends very much on the number of people exposed to the pollutant. Similarly, the magnitude of the welfare losses associated with the degradation of a natural resource dependson the number of people involved.)

(vi) Number of stakeholders interested in a solution. This will affect the design of the implementation procedure for the selected policy instrument.

The nature and extent of environmental problems themselves place distinct policy constraints upon decision makers in a variety of ways. For instance, economic instruments that may work for one set of environmental problems in one country may not be sufficient to address a more severe problem in another. Similarly, a less developed country with severe environmental problems will naturally face greater constraints than a developed country with more resources and fewer problems. Further, a country that is economically dependent upon a marginally profitable and polluting industry will have fewer policy options than countries with more diverse and profitable industries. Policymakers often have to make choices among which environmental problems to address, because the resources are not available to address all of the issues at one time.

In general, environmental problems can only be understood and addressed in the context of the larger economy and society. The state of economic development, cultural values, and population pressures, often constrains the options available to address problems. The level of economic development determines the type of environmental issues to be addressed and the effectiveness of the various environmental protection instruments available. For example, low levels of development will likely mean greater rural than urban environmental concerns. Less developed countries also have fewer available instruments to use. They have less tax base to enforce environmental protections laws and a restricted range of economic instruments. The industrial makeup of the economy is another critical factor. Many countries depend on one or a few major industries. Others have a diverse economic base. These conditions greatly impact the type of environmental instruments needed for environmental protection and natural resources management,

The appropriate policy response hinges on a clear and realistic understanding of **baseline conditions.** Sometimes this may mean a less effective policy on a theoretical basis is actually the most appropriate one, given institutional capabilities. Though every country wants to portray an image of clean and efficient governance, few nations can truly boast of such systems. The level of competence and honesty of any institution that will be used to develop, promulgate, monitor or enforce the policy in question needs to be realistically assessed. If these limitations are not recognized, there is strong likelihood that policy instruments will fail, leaving the underlying environmental problem unsolved. While improvement in the structure or performance of institutions can improve over time, it is unwise to depend on them in the short run. In particular, the following areas critical to the success of any environmental initiative need to be considered: Governmental capacity, Environmental agency power, Fiscal cash flow implications, Social, cultural, and demographic implications, and Economic conditions.

4.3.1.3. Making Policy Choices

Given the uniqueness of any given situation, it is difficult to offer specific guidance on how to make policy choices to address environmental problems. However, some general guidelines can help policymakers to choose the most appropriate options for further consideration. These include specifically the recognition of policy trade-offs and realistic assessments of policy limitations. The following practical guide have been recommended.

- **Choose the Simpler Approach**: Policy design should be commensurate with the problem to be solved. There is always need to avoid overly complicated policies. If the problem is local, local solutions may be best. If the problem involves a handful of industries with similar production processes, establishing a national trading system probably does not make sense as costs of control will be similar across plants. Simple easy to administer solutions, however, are often more difficult to arrive at, or even imagine, but they are almost always more efficient and effective.

- **Match the Policy to the Problem**. In the end, actual reduction of pollution or conservation of natural resources depends upon choosing the right policy instruments given baseline conditions, the problem to be solved, and stakeholder feedback. Obviously, the option with the highest efficacy, lowest side-effects and greatest feasibility given existing power and institutional dynamics would be best. However, it is unlikely that any option will score the highest for each category, so trade-offs will be needed. Unfortunately, there is no formula for finding the right balance. Box 4.4 below presents some common problems and policy instruments useful in addressing them.

- **Mitigate Hardships.** Policy proposals should include appropriate measures to ameliorate negative impacts, for example transitional support for displaced individuals or poor segments of society. Where policy implementation is anticipated to cause undue hardships on segments of the population, transitional measures need to be built into the initial policy package. Possibilities include phasing in limits slowly to avoid sudden changes in prices or access rights; exemptions for groups who face high compliance costs but are minor contributors to the problem; or transitional subsidies to highly affected groups. Solutions that mitigate hardships should adhere to the polluter pays principle as closely as possible, resisting the inevitable efforts by industry groups to have their entire transition costs shifted to the taxpayer. Aside from the reduction in hardship, the flanking measures play an important role in mitigating political opposition to the new policy.

- **Avoid Inappropriate Use of Economic Instruments.** It is important to understand and acknowledge the conditions under which the use of economic instruments is not likely to be appropriate. Box 4.5 identifies specific conditions where the use of economic instruments may not achieve the desired environmental and economic objectives while Box 4.6 examines an application of transferable quotas for international fisheries protection.

- **Use Subsidies Carefully.** In attempting to mitigate hardships, or to achieve political consensus, it is quite common to offer subsidies to affected parties. However, providing temporary or transitional subsidies to facilitate changes should be used sparingly since any subsidy distorts markets and makes them less efficient. In addition, they are often very difficult to end once started. Rather, subsidies should focus on protecting the poorest sectors of society from any severe impacts of the change. This could be done with:

  (i) Payments to affected poor individuals for transitional assistance. Examples are subsidies for the introduction of environmentally sound technologies, in situations where social benefits greatly exceed private benefits (e.g. the reduction of overgrazing among traditional herders), or in situations where payments can be decoupled from any activities causing environmental damage, and limited in time.

  (ii) Pricing mechanisms (such as offering subsidies flowing only to basic foodstuffs) in societies where central governments cannot be relied upon to provide direct subsidies to the poor.

  (iii) Support for subsistence sectors decoupled from environmentally damaging production and shifted to subsistence consumption.

- **Prioritize Options.** This has to do with comparing the final options across key criteria. Table 4.3 provides a simple template that can be used to compare the final options across key criteria. The use of a matrix ensures that important data and impact categories are compared for each option. Each separate option generates two columns in the table. The first, “Option Review” will provide very brief text summaries of the policy alternative. The second, “Ranking”, provides comparative rankings that will make policy comparisons easier to do. Ranking methods can be changed to suit needs and preferences (e.g. use of numbers rather than high, medium low; or by weighting some criteria more than others). Similarly, evaluation criteria can be modified as well to better reflect the objectives of policymakers. This type of comparison can be helpful in trying to decide amongst the final slate of options.

Box 4.4 Common Environmental Problems and Useful Policy Responses

Overuse of Natural Resources. Property rights-oriented approaches, such as granting or selling the rights to access or develop particular resources to specific groups, can work well in situations where current use patterns are depleting the resource base. Where informal access patterns by local users are codified, subsistence livelihoods can be protected while concurrently providing much improved direct incentives to manage the resource for the long-term.

Even in more international markets, permits that differentiate commercial and subsistence users can help achieve a balance between resource protection and employment. If consumption must be curbed, buy-out or phase-out of the existing de facto rights is a possibility.

Industrial Pollution - **Disparate Technologies**. Where emissions of pollutants come from many industrial sources, there is likely to be widely varying costs to abate the pollution. In these circumstances, there are often large efficiency gains from imposing pollution taxes, fees, or tradable permits relative to mandatory standards under a command and control regime.

Industrial Pollution - Standard Technology, Few Producers. Where there are few producers, all relying on similar production technologies, disparities in control costs are generally much lower. These circumstances suggest minor gains from trading alongside potentially large oversight costs to create a market. Command and control regulatory approaches may be the more efficient option.

Known Damage Thresholds. Where regulators have a good sense of the point at which emissions will cause health problems or ecosystems begin to fray, tradable permits are often the best choice. Caps on emission/extraction can be set in advance, either based on absolute values (e.g., tons of salmon that can be caught) or on relative values (e.g., percent of total allowable catch), allowing markets to allocate the rights efficiently. Policy adjustments should be made on a regular basis to adapt to changing conditions or errors in the initial caps.

Publicly Provided Services. The objective of policies affecting publicly owned service organizations (e.g. water, sewer, or electrical utilities) is to institute pricing that achieves full recovery of costs through user fees, but with a rate design that protects the poor. Attempts to cover costs of the enterprises often bring to light their inefficiencies, increasing pressure for improved management and governance structures. The combination of revenue collection and increased organizational efficiency can be a powerful help to governments. Improved cost recovery can make system upkeep easier, with resultant improvements in efficiency of resource use, and more feasible system extensions, often with associated equity benefits such as providing electricity or sewage services to poorer regions for the first time.

Box 4.4. Contd.

Highly Politicized Government Enterprises. Influencing government-owned enterprises, especially in highly politicized natural resource extraction areas (e.g. oil, natural gas, and other minerals), presents special challenges. Such enterprises face difficult obstacles in preventing corruption given large cash flows and poor transparency and therefore in instituting appropriate environmental controls (government litigation against itself being uncommon). In such cases, most experts believe that both the fiscal and environmental well-being of the country can be served through privatizing the enterprise if not ownership of the resource itself. This can be done either through a direct sale, or by floating a portion of the company in international stock markets. Stock market listing requirements provide important leverage to facilitate disclosure and transparency, and to overcome special interests benefiting from the status quo.

Transitioning to New Technology. Moving an existing market structure to one that includes more environmentally-friendly approaches involves multiple challenges: developing a technology that works; convincing firms to use the technology; and ensuring that the final product can actually be sold.

Some market shifts that mostly require changes in management (e.g., soil conservation on farms) can often be accomplished by making the continuation of existing subsidies contingent on the adoption of sustainable practices.

Where new equipment must enter the marketplace but is still more expensive, policies should reward initiatives once they are sold. Therefore, rather than subsidizing research and development (R&D) or plant construction for wind power, a subsidy per unit of wind power purchased in the market would be provided. (**Source**: UNEP,2009. p.192)

Box 4.5. When not to Use Economic Instruments

Emergency Conditions. When problems have severe implications, emergency conditions arise, and behaviour needs to stop immediately, directive bans may be more appropriate. Property rights or licensing approaches could work where some activity, albeit a much lower level, would be acceptable.

Excessive Monitoring Costs. Where monitoring costs are too high to achieve a specific environmental outcome, as when there are a large number of very small transactions (e.g., emissions trades), command and control instruments may be a better fit. Similarly, where there are a very small number of homogenous parties, emissions trading would not have an effective market and few efficiency gains would be achieved through trading. Monitoring and oversight costs would exceed the benefit of economic instruments.

Fragmented Oversight Authority. Where authority to set and enforce regulations for the implementation of economic instruments is highly fragmented across institutions, effective oversight of market-based instruments might become impossible. In such cases, command and control instruments tailored to the existing oversight authorities might be more efficient.

Social Stigma. Societal factors can also make market-based approaches more difficult. For example, communal societies may not adapt well to individual members of the society holding particular rights or paying particular fees. In other societies, the activities that would be affected by the economic instruments may have a close link to social status, generating strong resistance to change.

An example is the loss of cattle (and with it, prestige) if market-based individual grazing rights policies are attempted in some cultures. However, in these circumstances, economic instruments might work when applied at the community level since the communal decision-making can maintain the existing social hierarchy as access rights are granted.

Insurmountable Opposition. Where political power and interest group factions remain strong, policymakers need to judge the most prudent course. Political power can be used when establishing economic instruments to generate loopholes, exemptions or windfalls, in exactly the same way as this power is applied in command and control instruments. Privatization can be used as a front for corrupt sales to transfer state-owned assets to private parties with no gain to the public.

High Level of Dislocation. Where large numbers of people will be displaced or unemployed as a result of economic instruments and there is little that can be done to mitigate hardships, caution is required.

(**Source**: UNEP,2009. p.194)

Box 4.6 Transferable Quotas for International Fisheries Protection

Fisheries have long been a “commons” problem, since fish dwell in unmanaged ecosystems accessible by many countries. Historical controls to address this problem have focused on restricting access. Nationalization of 200 miles of coastline by most countries helped reduce fishing pressure for a while, by curbing access of foreign fleets to domestic waters. However, even with such restrictions, problems remained. Two main economic counter currents undermined the effect of restricted access to the fisheries.

These were:

- Continual technical improvements in fleets that made each boat a more efficient vessel for harvesting fish and,
- Large subsidies of fishing-related operations and capital equipment (e.g., subsidized loans for boats) created a massive overcapacity of vessels. The World Bank has estimated that during the 1990s, annual subsidies were equal to between 20 and 25 percent of global fishery revenues.

The combination of these two developments has depleted many fisheries to the point of total collapse of the fishery.

Using transferable quotas over the past 30 years, many countries have implemented market-based approaches to ration access to fisheries and manage both local and international fisheries. Variously called Individual Transferable Quotas (ITQs) or Individual Fishery Quotas (IFQs), the rights allow the holder to catch a specified proportion of the total allowable catch each year. The total catch represents the central government’s estimate of how many pounds of a particular fish species can be sustainably harvested.

The theory of ITQs is clear. Where there once was unlimited and free access to fish, users must now be licensed. This has a number of advantages:

- With quotas users can space out their catch more regularly without fearing that others will overuse the resource, enabling them to fish more when prices are high, increasing their profits.
- The aggregate catch of the vessels is limited, ensuring sufficient fish survive to rebuild stocks.
- Each license holder has an incentive to ensure other vessels do not fish illegally, since this reduces the available catch for license holders and depresses the value of the licenses on the spot market, which existing quota holders can sell.

The Organization for Economic Co-operation and Development (OECD) has reviewed 31 fisheries across six countries using some variant of this approach and concluded that catch levels were maintained at or below catch limits in 24 cases. In 23 cases, the permits also improved the cost-effectiveness and profits of the fishery. While overall employment generally fell, part-time and seasonal jobs were often replaced by more stable, year-round work.

The success of the programmes seems to be dependent upon some key criteria:

- **Accurate Estimates of Sustainable Catch.** If the total catch values are too high, transferable permits have the perverse effect of increasing the cost-effectiveness of the unsustainable exhausting the resource. OECD noted that there were at least temporary declines in fish stocks within 24 fisheries. This seems to have been caused by a basic problem in the way total catch was calculated, and that the error eliminated many of the environmental and ecological benefits of the economic instrument.

Box 4.6. Contd.

- **Consistent Administration.** In the Netherlands (sole and place fisheries) and Norway (cod fishery), ITQs failed to halt the increase in catch because license holders found that the state was shutting entire fisheries down even if individual quota holders had not yet met their quotas. As a result, quota holders continued to have a "race to fish" to exhaust their catch limits first before access was closed off.

- **Resistance to Political Pressure.** Errors in total catch values may not all be technical. Regulators in South Africa have been under continued and intense political pressure to increase total catch figures, irrespective of the environmental cost of doing so. Such pressure exists in most countries, but total catch figures are most likely to be manipulated for private gain where institutions are weak or corruption is widespread.

- **Correct and Complete Information.** Catch quotas are often based on landing statistics. Many fishermen destroy catch at sea to produce acceptable landing numbers making it impossible to reconcile the landing statistics with the actual pressure placed on marine ecosystems. It has been suggested that a post-landing spot market for ITQs, allowing fisherman to purchase excess quotas, may alleviate this pressure to some degree.

- **Avoidance of High Grading.** In a practice called "high grading" fishing crews discard smaller fish (that often die) at sea in order to maximize the value of the catch that is officially landed. Differential landing taxes, with higher levies on bigger fish, in theory could make fishermen neutral with regards to the maturity of their catch. However, the cost of monitoring needed to accurately set and implement such taxes could be quite large.

Thus far, fisheries managers have steered clear of multi-catch fisheries because of the complications involved. The programmes have instead been targeted to single species. While bundled ITQs covering common mixtures of species could be created, implementing it in practice is difficult as by-catch (i.e. the catch of unwanted species) is likely to vary by region. (Source: UNEP, 2009).

Table 4.3. Policy Ranking Template

Policy parameter	Option review*	Ranking* (H,M,L)
Description		
Main policy		
Choices re: distribution of initial rights, ability to transfer, duration and caps		
Performance		
Environmental efficacy		
Complexity		
Cost of implementation and operation		
Anticipated side-effects		
Social: highly impacted groups (exposure, job loss, increased poverty)		
Short-term economic impacts		
Long-term economic impacts		
Trade and competitiveness impact		
Proposed flanking measures		
Feasibility		
Institutional capability to implement?		
Powerful opposition?		
Other factors of interest/concern		

* Each of the final policy options should have its own review and ranking columns. (**Source:** UNEP, 2009. p.196)

4.3.2 Evaluation Criteria

4.3.2.1 Introduction

What criteria should be used to evaluate environmental policies? Box 4.7 provides a listing of some yardsticks. Among these criteria, cost effectiveness has been a traditional focus both at the theoretical and empirical level. However, it is obvious from the listing that cost effectiveness is not the only important, and is not even likely to be the most important, criterion in many contexts. More recently, the role of political feasibility and distributional issues have gained traction. In this subsection, we will examine the core issues in cost effectiveness as an evaluation criterion after which we will focus on political feasibility and distributional issues.

Box 4.7 Evaluating Economic Instruments

Environmental Effectiveness: Are emissions levels or resource depletion rates falling? Are ambient concentrations in the surrounding environment declining? These are critical metrics to establish both baseline values and measurements over time. Unfortunately, even this basic data is often lacking.

Economic Efficiency: Are costs of emissions rights stable or declining? Are they less expensive than projected in advance? (Falling values normally indicate that businesses are finding more efficient abatement methods.) Are new abatement technologies entering the market? Are trades being used? (Falling values with declining trades suggest either that new non-polluting options have emerged or that polluters are not purchasing required permits).

Administration and Compliance Costs: Has the public sector implemented an effective administrative oversight programme for the policies? How expensive is this to run relative to the value of trades occurring, emissions reductions realized, or anticipated cost of command and control programmes? How expensive are the administrative costs to the private sector relative to those normally incurred under a command and control approach? Are institutions cooperating to achieve the policy objective, or are efforts being blocked?

Revenue Generation: Are user fees sufficient to cover the full costs of providing particular public services? Are fees appropriately levied on different user groups? Are environmental taxes high enough to trigger appropriate price increases in the products/production processes of concern? Are revenues retained to support additional environmental protection efforts or diverted to the general treasury?

Political feasibility: Is the policy politically feasible? Is it likely to gain the support of the Legislature, bureaucrats or policy-makers? Is the implementation feasible? Is it going to be resisted by those who hold de facto political power, civil society, or those who have ability to influence public opinion?

Distributional Issues: How will the policy affect the distribution of resources; particularly, how will it affect the poor or less-privileged? Is it going to redistribute resources in favour of the more-privileged in society?

Wider Economic and Social Effects: Are there noticeable (positive or negative) effects on employment, poverty, trade, competitiveness, growth, or rates of innovation that can be reasonably attributed to the environmental policies being evaluated? Where these impacts are negative, are they transitory or permanent? Can policy modifications mitigate the transitional dislocations?

Source: Adapted with modifications from OECD, (1997) Evaluating Economic Instruments for Environmental Policy, pp. 91-99; UNEP (2009). p198 and Damon and Sterner (2012) “Policy Instruments for Sustainable Development at Rio +20, Journal of Environment & Development 21(2) 143–151.

4.3.2.2. Cost-Effective Policies for Uniformly-Mixed Fund Pollutants

Cost effectiveness relates to achieving the target control level in a manner that minimizes the cost of control. For the purpose of this lecture, we will focus on pollution.

For uniformly-mixed fund pollutants, the damage caused depends on the amount entering the atmosphere and is relatively insensitive to where the emissions are injected into the atmosphere. Assume for example, two emission sources (firm 1 and firm 2); each of them is currently emitting 15 units making a total 30 units. Suppose that two firms can control emissions at the following marginal costs:

$$MC_1 = \$100q_1 \qquad (4.16)$$

and

$$MC_2 = \$200q_2 \qquad (4.17)$$

where q_1 and q_2 is, respectively, the amount of emissions reductions by the first and second firm. Assume the regulatory authorities have, however, set a total emission target of 15 units so that a reduction of 15 units is necessary. How should this 15-unit reduction be allocated between the two sources in order to minimize the total cost of the reduction?

Assume the government intend to use a CAC policy instrument, such as emissions standard: In the absence of any information on control costs at its disposal, the easiest method would be simply to allocate each source an equal reduction. That is to say, each firm reduces emissions by 7.5 units. By integrating their respective MC functions at the values of $q_1 = q_2 = 7.5$ we can find the total cost of emission reduction for each firm. Summing up, we get a total cost of reduction equal to \$ 8,437.50.

Now, assume that instead of emission standard (a CAC policy), the regulatory agency decides to use a market-based instrument, like an emission charge, a fee levied on each unit of pollution. The total payment any source would make to the government could be found by multiplying the fee times the amount of pollution emitted. Here, each firm has an incentive to reduce pollution because paying the fees costs the firm money. How much pollution control would the firm choose in this circumstance?

A profit-maximizing firm would control, rather than emit, pollution whenever it proved cheaper to do so. Consider Figure 4.8 which sketches the marginal cost function for firm 1. The level of uncontrolled emission is 15 units and the emissions charge is T. Thus, if the firm were to decide against controlling any emissions, it would have to pay T times 15, represented by area 0TBC. It is obvious that the firm will not choose this option because it can control some pollution at a lower cost than paying the emissions charge. It would profit the firm more to reduce emissions until the marginal cost of reduction is equal to the emissions charge.

$$MC_1 = \$100q_1 = \mathrm{T}q_1 \qquad (4.18)$$

As illustrated in the diagram, the firm would minimize its cost by choosing to clean up 10 units of pollution and to emit 5 units. At this allocation the firm would pay control costs equal to area 0AD and total emissions charge payments equal to area ABCD. Doing this allows the firm to save 0AT in cost.

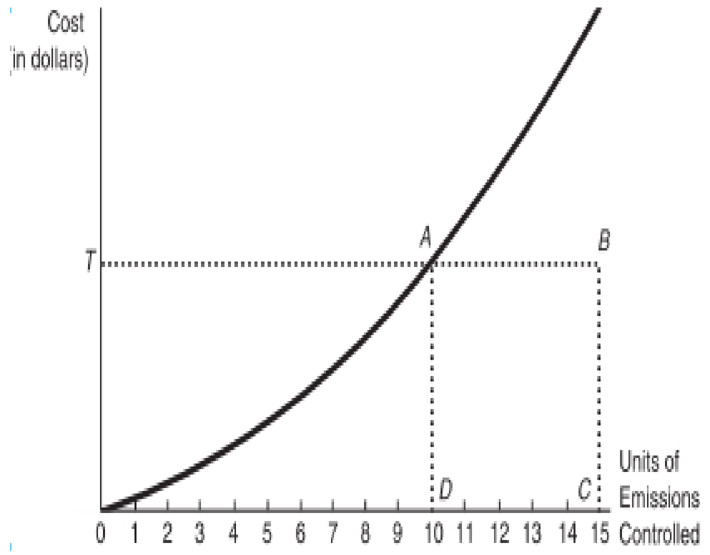


Fig. 4.8a. Cost-Minimizing Control of Pollution with an Emissions Charge (**Source:** Tietenberg & Lewis, 2012. p371)

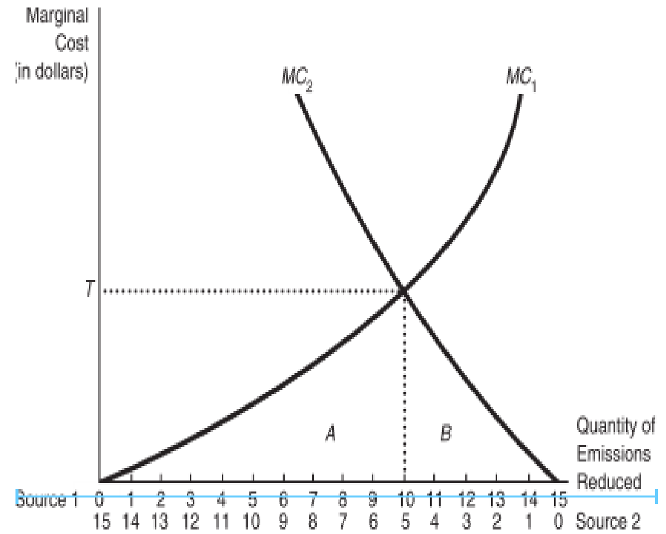


Fig. 4.8b Cost-Effective Allocation of a Uniformly Mixed Fund Pollutant **(Source**: Tietenberg & Lewis, 2012. p.369)

The second firm will follow the same cost minimization principle and pollute up to 10 units and clean up 5 units. Since emissions charge, is the same for both firms, they will independently choose levels of control consistent with equal marginal control costs.

$$MC_1 = MC_2 = \text{T} \qquad (4.19)$$

The result is illustrated in Figure 4.8b. In the diagram, the marginal cost of control for firm 1, MC_1, is measured from the left-hand axis, while the marginal cost of control for firm 2, MC_2, is measured from the right-hand axis. A total 15-unit reduction is achieved for every point on the graph; each point represents some different combination of reduction by the two sources. Thus, the diagram represents all possible allocations of the 15-unit reduction between the two sources. All points in between represent different allocations between the two firms. Indeed, we can use equation (4.) to derive the algebraic solution illustrated in Fig. 4.8b by equating (4.16) and (4.17), given that $q_1 + q_2 = 15$ and solving for the values of q_1 and q_2 that satisfy the conditions, It is not difficult to see that these values are $q_1 = 10$ and $q_2 = 5$.

The condition indicated in (4.19) is the cost effectiveness criterion. It yields the cost-minimizing allocation that achieves the pollution target. In other words, cost-effectiveness is achieved when firms equalize their marginal abatement costs (the equi-marginal principle that underlies the efficiency principle). Given increasing marginal costs of pollution control, the cost of achieving a given reduction in emissions will be minimized if and only if the marginal costs of control are equalized for all emitters. In Figure 4.8b this is demonstrated by the fact that the marginal cost curves for the two firms cross at the cost-effective allocation.

It is easy to show that the total cost of emission control is lower in this case, compared to under the emission standard policy. Substituting q_1= 10 and q_2 = 5 into the integral of the MC functions for the firm and adding up gives a total cost of \$7, 500 indicating a cost saving of \$8,437.50 - \$ 7,500 = \$937.59. Thus, by using economic instruments, the economy is able to reduce its pollution abatement costs. As long as the control authority imposes the same emissions charge on all sources, the resulting incentives are automatically compatible with minimizing the costs of achieving that level of control. This is true in spite of the fact that the control authority may not have sufficient knowledge of control costs for each firm.

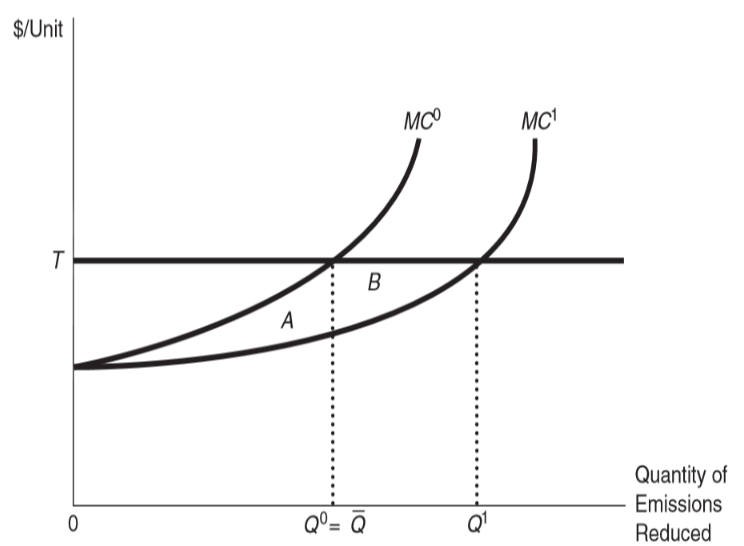


Fig. 4.9 Cost Savings from Technological Change under emission charges (Source: Titenberg & Lewis, 2012. p.373)

Emission charges not only causes cost-minimizing sources to choose a cost- effective allocation of the control responsibility, it also stimulates the development of newer, cheaper means of controlling emissions, as well as promoting technological progress. With an emissions charge system, the firm saves money by adopting cheaper new technologies. As long as the firm can reduce its pollution at a marginal cost lower than the emission charge, it pays to adopt the new technology.[20] This is illustrated in Figure 4.9. The firm

[20] In contrast, under emission standard, firms have an incentive to hide technological changes from the control authority. This is because control authorities base the emissions standards on specific technologies. As new technologies are discovered by the control authority, the standards are tightened. These stricter standards force firms to bear higher costs.

saves A and B by adopting the new technology and voluntarily increases its emissions reduction from Q_0 to Q_1.

However, it has a major drawback in the sense that it is not possible to determine onset what the efficient level of emission will be. Put differently, it is not possible to know ahead the emission charge that will be consistent with the target (desired) level of emission. How high should the charge be set to ensure that the resulting emissions reduction is the desired level? Without having the requisite information on control costs, the control authority cannot establish the correct tax rate on the first try.[21]

It is possible, however, to develop an iterative, trial-and-error process to find the appropriate rate. This process is initiated by choosing an arbitrary charge rate and observing the amount of reduction that occurs when that charge is imposed. If the observed reduction is larger than desired, it means the charge should be lowered; if the reduction is smaller, the charge should be raised. The new reduction that results from the adjusted charge can then be observed and compared with the desired reduction. Further adjustments in the charge can be made as needed. This process can be repeated until the actual and desired reductions are equal. At that point the correct emissions charge would have been found. But during the trial-and-error period of finding the appropriate rate, firms would be faced with a volatile emissions charge which makes planning for the future difficult. Investments that would make sense under a high emissions charge might not make sense when it falls. This does not bode well for both policy-makers and business firms.

It is believed that the use of Cap-and-Trade helps to overcome this limitation. Under this system, all sources face a limit on their emissions and they are allocated (or sold) allowances to emit. Each allowance authorizes a specific amount of emissions (commonly 1 ton). The control authority issues exactly the number of allowances needed to produce the desired emissions level. These can be distributed among the firms either by auctioning them off to the highest bidder or by granting them directly to firms free of charge (an allocation referred to as "gifting"). However, they are acquired, the allowances are freely transferable; they can be bought and sold. Firms emitting more than their holdings would buy additional allowances from firms who are emitting less than authorized. Any emissions by a source in excess of those allowed by its allowance holdings at the end of the year would cause the source to face severe monetary sanctions. Figure

[21] Firms generally have a large menu of options for controlling the amount of pollution they inject into the environment. The cheapest method of control will differ widely not only among industries, but also among plants in the same industry. Generally, plant managers are able to acquire this information for their plants when it is in their interest to do so. However, the government authorities responsible for meeting pollution targets are not likely to have this information. Since the degree to which these plants would be regulated depends on cost information, it is unrealistic to expect these plant managers to transfer unbiased information to the government. Plant managers would have a strong incentive to overstate control costs in hopes of reducing their ultimate control burden.

4.10 below, which treats the same set of circumstances as in Figure 4.8b illustrates why this system automatically leads to a cost-effective allocation.

Consider first the gifting alternative. Suppose that the first source was allocated 7 allowances (each allowance corresponds to one emission unit). Because it has 15 units of uncontrolled emissions, this would mean it must control 8 units. Similarly, suppose that the second source was granted the remaining 8 allowances, meaning that it would have to clean up 7 units. Notice that both firms have an incentive to trade. The marginal cost of control for the second firm (MC_2 = 200 = C in the diagram) is substantially higher than that for the first (MC_2 = 200 = A) in the diagram. The second source could lower its cost if it could buy an allowance from the first source at a price lower than C. Meanwhile, the first source would be better off if it could sell an allowance for a price higher than A. Because C is greater than A, grounds for trade certainly exist. A transfer of allowances would take place until the first source had only 5 allowances left (and controlled 10 units), while the second source had 10 allowances (and controlled 5 units). At this point, the allowance price would equal B, because that is the marginal value of that allowance to both sources, and neither source would have any incentive to trade further. The allowance market would be in equilibrium.

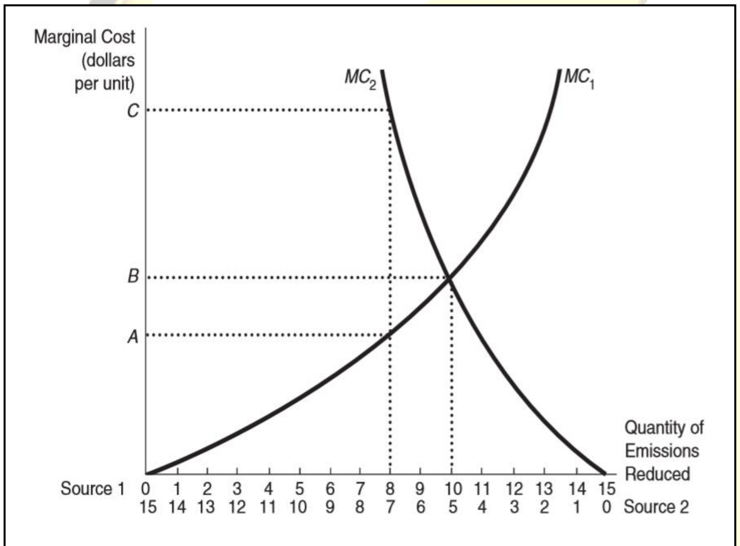


Fig. 4.10 Cost-Effectiveness and Emissions Trading (Source: Titenberg & Lewis, 2012. p.374

Notice that the market equilibrium for an emission-allowance system is the cost-effective allocation! Simply by issuing the appropriate number of allowances (15) and letting the market do the rest, the control authority can achieve a cost-effective allocation without having even the slightest knowledge about control costs. This system allows the government to meet its policy objective, while allowing greater flexibility in how that objective is met. Even if the allowances were auctioned off, the outcome will be the same. The incentives created by this system ensure that sources use this flexibility to achieve the objective at the lowest possible cost. This remarkable property has been responsible for the prominence of this type of approach in current attempts to reform the regulatory process.

4.3.2.3 Cost-effective Policy for Nonuniformly-mixed Pollutants

The problem is more complicated when dealing with nonuniformly mixed surface pollutants. For these pollutants, the policy must be concerned not only with the weight of emissions entering the atmosphere, but also with the location and timing of emissions. For nonuniformly mixed pollutants, it is the concentration in the air, soil, or water that counts. This is measured as the amount of pollutant found in a given volume of air, soil, or water at a given location and at a given point in time.

It is easy to see why pollutant concentrations are sensitive to the location of emissions. Suppose that three emissions sources are clustered and emit the same amount as three distant but otherwise-identical sources. The emissions from the clustered sources generally cause higher pollution concentrations because they are all entering the same volume of air or water. Because the two sets of emissions do not share a common receiving volume, those from the dispersed sources result in lower concentrations. This is the main reason why cities generally face more severe pollution problems than do rural areas; urban sources tend to be more densely clustered. The timing of emissions can also matter in two rather different senses. First, when pollutants are emitted in bursts rather than distributed over time they can result in higher concentrations. Second, the time of year in which some pollutants are emitted can matter.

Since the damage caused by nonuniformly mixed surface pollutants is related to their concentration levels, the search for cost-effective policies for controlling these pollutants focuses on the attainment of ambient standards. Ambient standards are legal ceilings placed on the concentration level of specified pollutants in the air, soil, or water. They represent the target concentration levels that are not to be exceeded. A cost-effective policy results in the lowest cost allocation of control responsibility consistent with ensuring that the predetermined ambient standards are met at specified locations called receptor sites. We will analyze this first in the case of a single receptor, and later extend to the case of many receptors.

Since emissions are what can be controlled, but the concentrations at the receptor, R are the policy target, our first task must be to relate the two. (In a single receptor case, R = 1). This can be accomplished by using a transfer coefficient. A transfer coefficient (a_i) captures the constant amount the concentration at the receptor will rise if source *i* emits one more unit of pollution. Using this definition and the knowledge that the a_is are constant, we can relate the concentration level at R to emissions from all sources:

$$K_R = \sum_{i=1}^{I} a_i E_i + B \qquad (4.20)$$

where K_R = concentration at the receptor, E_i = emissions level of the i^{th} source, I = total number of sources in the region, B = background concentration level (resulting from natural sources or sources outside the control region).

In Table 4.4, we present a numerical example involving two which are assumed to have the same marginal cost curves for cleaning up emissions but are located at different distances from the receptor. The first source is closer to the receptor, so it has a larger transfer coefficient than the second (1.0 as opposed to 0.5). The objective is to meet a given concentration target at minimum cost. Column 3 of the table translates emissions reductions into concentration reductions for each source. This is product of the emissions reduction and the transfer coefficient. Column 4 records the marginal cost of each unit of concentration reduced and is derived by dividing the marginal cost of the emissions reduction by the transfer coefficient (this translates the marginal cost of emissions reduction into a marginal cost of concentration reduction).

Table 4.4 Cost-Effectiveness for Nonuniformly Mixed Pollutants: A Hypothetical Example

Emissions Units Reduced	Marginal Cost of Emissions Reduction (dollars per unit)	Concentration Units Reduced[1]	Marginal Cost of Concentration Reduction (dollars per unit)[2]
Source 1 ($a_1 = 1.0$)			
1	1	1.0	1
2	2	2.0	2
3	3	3.0	3
4	4	4.0	4
5	5	5.0	5
6	6	6.0	6
7	7	7.0	7
Source 2 ($a_2 = 0.5$)			
1	1	0.5	2
2	2	1.0	4
3	3	1.5	6
4	4	2.0	8
5	5	2.5	10
6	6	3.0	12
7	7	3.5	14

[1]Computed by multiplying the emissions reduction (column 1) by the transfer coefficient (a_i).

[2]Computed by dividing the marginal cost of emissions reduction (column 2) by the transfer coefficient (a_i).

Source: Tietenberg & Lewis, 2012. p.379

Suppose the concentration at the receptor has to be reduced by 7.5 units in order to comply with the ambient standard. The cost-effective allocation would be achieved when the marginal costs of concentration reduction are equalized for all sources. In the Table, this occurs when the first source reduces 6 units of emissions (and 6 units of concentration) and the second source reduces 3 units of emissions (and 1.5 units of concentration). At this allocation the marginal cost of concentration reduction is equal to \$6 for both sources. By adding all marginal costs for each unit reduced, we calculate the total variable cost of this allocation to be \$27. From the definition of cost-effectiveness, no other allocation resulting in 7.5 units of concentration reduction would be cheaper.

With the above framework, we can evaluate various policy approaches that the control authority might use beginning with ambient charge.

An ambient charge will take the form

$$t_i = a_i F \tag{4.21}$$

where t_i is the per-unit charge paid by the i^{th}source on each unit emitted, a_i is the i^{th} source's transfer coefficient, and *F* is the marginal cost of a unit of concentration reduction, which is the same for all sources. In our example, *F* is \$6, so the first source would pay a per-unit emissions charge of \$6, while the second source would pay \$3. Unlike in the case of uniformly mixed pollutant in which a cost-effective allocation required that all sources pay the same charge, here where the objective is to meet an ambient standard at minimum cost, the sources pay different charges because their transfer coefficients differ.

How can the cost-effective t_i be found by a control authority with insufficient information on control costs? The transfer coefficients can be calculated using knowledge of hydrology and meteorology.[22] However, the marginal cost of a unit of concentration reduction, *F* cannot be so determined. Here a striking similarity to the uniformly mixed case becomes evident. Any level of *F* would yield a cost-effective allocation of control responsibility for achieving some level of concentration reduction at the receptor. That level might not, however, be compatible with the ambient standard. We could ensure compatibility by changing *F* in an iterative process until the desired concentration is achieved. If the actual pollutant concentration is below the standard, the tax could be lowered; if it is above, the tax could be raised. The correct level of *F* would be reached when the resulting pollution concentration is equal to the desired level. That equilibrium allocation would be the one that meets the ambient standard at minimum cost.

It is worth considering what is lost if the simpler emissions charge system (where each source faces the same charge) is used to pursue a surface-concentration target. Another way of saying that is that we ignore location. Can location be safely ignored? From Table 8.3, a uniform emission charge equal to \$5 would achieve the desired 7.5 units of reduction (5 from the first source and 2.5 from the second). Yet the total variable cost of this allocation (calculated as the sum of the marginal costs) would be \$30 (\$15 paid by each source). This is \$3 higher than the allocation resulting from the use of ambient charge discussed earlier. In addition, with a uniform emissions charge, 10 units of emission are cleaned up, whereas with the ambient charge, only 9

[22] Thus, the cost-effective allocation of control responsibility for achieving surface-concentration targets places a larger information burden on control authorities; they have to calculate the transfer coefficients.

units are cleaned up even though the same concentration target is achieved. Thus, the ambient charge results in a lower cost allocation than the emissions charge because it results in less emissions control.

With the ambient charge, we have the same problem that we encountered with emissions charges in the uniformly mixed pollutant case—the cost-effective level can be determined only by an iterative process. As in the case of uniformly mixed pollutants, emissions trading can help get around this problem when the allowance trading system is designed in the correct way. An ambient allowance market (as opposed to an emissions allowance market) entitles the owner to cause the concentration to rise at the receptor by a specified amount. Using ΔK_R to represent this permitted rise and E to indicate the units of emissions allowed to the i^{th} source, we can see from Equation (4.20) that

$$\frac{\Delta K_R}{a_i} = \Delta E_i \qquad (4.22)$$

The larger the transfer coefficient (i.e., the closer the source is to the receptor), the smaller the amount of emissions legitimized by the allowances held by that firm. Proximate sources must purchase more allowances than distant sources to legitimize a given level of emissions. In this ambient allowance market, the sources pay the same price for each allowance (with respect to Table 4.4, this will be $6) but the amount of emissions allowed by each allowance varies from location to location. The market automatically determines this common price, and the resulting allocation of allowances is cost-effective. This cost-effective system is called an *ambient allowance system* to differentiate it from the *emissions allowance system*, which is used to achieve a cost-effective allocation of control responsibility for uniformly mixed pollutants.

To fix ideas, using equation (4.20), suppose our two sources want to trade permits with the first source buying from the second. To maintain the same concentration level before and after the trade, we must ensure that

$$a_1\Delta E_1 = a_2\Delta E_2 \qquad (4.23)$$

where the subscripts refer to the first source and second source and the ΔE_i refers to a change in emissions by the i^{th} source. Solving this for the allowable increase in emissions by the buyer yields

$$\Delta E_1 = \frac{a_2}{a_1}\Delta E_2 \qquad (4.24)$$

For a_2 = 0.5 and a_1 = 1.0, this equation suggests that for each allowance traded, the buyer (the first source) is allowed to emit only one-half the amount of emissions allowed by that same allowance to the seller. After this trade, the total amount of emissions by both sources goes down.[23] This could not happen in an emissions allowance system, since the design of those allowances causes all trades to leave emissions (but not concentrations!) unchanged.

This analysis generalizes easily to the case where we have many receptors. The cost-effective ambient charge paid by any source would, in this case, be

$$T_i = \sum_{j=1}^{J} a_{ij} F_i \qquad (4.25)$$

where T_i = charge paid by the i^{th} source for each unit of emissions

a_{ij} = transfer coefficient that translates emissions by source *i* into concentration increases at j^{th} receptor

J = number of receptors

F_j = monetary fee associated with the j^{th} receptor

Thus, the source has to pay a charge that incorporates its effect on all receptors. The control authority could manipulate F_j for each receptor location until the desired concentration level is achieved at that receptor.

The extension of the ambient allowance system to the many-receptor case requires that a separate allowance market be created for each receptor. The price prevailing in each of these markets would reflect the difficulty of meeting the ambient standard at that receptor. All other things being equal, ambient allowance markets associated with receptors in heavily congested areas could be expected to sustain higher prices than those affected by relatively few emitters.

Since both the ambient allowance and the ambient charge systems take location into account, when these policies are chosen, the marginal cost of emissions control varies from location to location. Sources located in heavily populated portions of the region would pay higher marginal costs, since their emissions have a greater impact on the receptors of interest. This create incentives for new sources to choose their location carefully. Since heavily polluted areas have high control costs, new firms have some incentive to locate elsewhere, even though pollution-control expenditures are only part of the costs a firm considers when deciding where to locate. For nonuniformly mixed pollution problems, where the emissions occur is important and relocation may be one way to approach the least cost allocation. With the ambient allowance and charge systems, this is precisely what occurs.

However, in practice, ambient charge and allowance systems have proved to be excessively complex to implement. Regulatory agencies often employ a number of rule-of-thumb procedures designed to deal adequately with spatial issues while promoting cost-effectiveness. For a review of these approaches, where they have been applied, and the evidence on their success, see Tietenberg (1995).

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[23] Emissions would rise with ambient allowance trades if the transfer coefficient of the seller was larger than that of the buyer

4.3.2.4. Cost-effectiveness and Renewable Resources

The following case studies applies the results from comparing command-and-control and market-based policies to overharvesting of renewable resources.

Box 4.8. The Relative Effectiveness of Transferable Quotas and Traditional Size and Effort Restrictions in the Atlantic Sea Scallop Fishery

Theory suggests that transferable quotas will produce more cost-effective outcomes in fisheries than traditional restrictions, such as minimum legal size and maximum effort controls. Is this theoretical expectation compatible with the actual experience in implemented systems? In a fascinating study, economist Robert Repetto (2001) examines this question by comparing Canadian and American approaches to controlling the sea scallop fishery off the Atlantic coast. While Canada adopted a transferable quota system, the United States adopted a mix of size, effort, and area controls. The comparison provides a rare opportunity to exploit a natural experiment since scallops are not migratory and the two countries use similar fishing technologies. Hence, it is reasonable to presume that the differences in experience are largely due to the difference in management approaches. What were the biological consequences of these management strategies for the two fisheries?

- The Canadian fishery was not only able to maintain the stock at a higher level of abundance, it was also able to deter the harvesting of undersized scallops.
- In the United States, stock abundance levels declined and undersized scallops were harvested at high levels. What were the economic consequences?
- Revenue per sea-day increased significantly in the Canadian fishery, due largely to the sevenfold increase in catch per sea-day made possible by the larger stock abundance.
- In the United States, fishery revenue per sea-day fell, due not only to the fall in the catch per day that resulted from the decline in stock abundance, but also to the harvesting of undersized scallops.
- Although the number of Canadian quota holders was reduced from nine to seven over a 14-year period, 65 percent of the quota remained in its original hands. The evidence suggests that smaller players were apparently not at a competitive disadvantage.

What were the equity implications?

- Both U.S. and Canadian fisheries have traditionally operated on the "lay" system, which divides the revenue among crew, captain, and owner according to preset percentages, after subtracting certain operating expenditures. This means that all parties remaining in the fishery after regulation shared in the increasing rents. In this fishery at least, it seems that the expectations flowing from the theory were borne out by the experience.

Source: Robert Repetto. "A Natural Experiment in Fisheries Management," Marine Policy Vol. 25 (2001): 252–264; Also in Titenberg and Lewis, p343.

Box 4.9. Reducing Emissions from Deforestation and Forest Degradation (REDD): A Twofer?

According to the United Nations, deforestation and forest degradation, through agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires, etc., account for nearly 20 percent of global greenhouse gas emissions, more than the entire global transportation sector and second only to the energy sector. In response, the United Nations has set up a program to reduce these emissions by reducing the forest degradation in developing countries where they occur. Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and to invest in low-carbon paths to sustainable development. According to this scheme, nations would receive payments for emissions-reduction credits determined on the basis of actual reductions in forest emissions measured against agreed-upon baselines. Although the details of this program remain to be worked out, these credits could, in principle, be sold in the international compliance carbon markets (where they could be used in combination with domestic reductions to meet assigned national targets) or voluntary carbon markets (where they could be used to pursue other organizational goals, such as demonstrating carbon neutrality). The promise of this program is that it offers opportunities to make progress on two goals at once: (1) reducing forest degradation and (2) reducing emissions that contribute to climate change. The challenges, which are far from trivial, are to establish baselines that are both fair and effective and to assure that monitoring and verification procedures are sufficiently rigorous as to provide reliable, accurate measures of actual emissions reductions.

Sources: Government of Norway (2009). Reducing Emissions from Deforestation and Forest Degradation (REDD): An Options Assessment Report. An electronic copy of this report is available at http://www. REDD-OAR.org; and the United Nations REDD website (http://www.un-redd.org/), Titenberg and Lewis, p316

Royalty Payments and Biodiversity Preservation

One potential source of revenue for biodiversity preservation involves taking advantage of the extremely high degree of interest by the pharmaceutical industry in searching for new drugs derived from these biologically diverse pools of flora and fauna. Establishing the principle that nations containing these biologically rich resources within their borders would be entitled to a stipulated royalty on any and all products developed from genes obtained from these preserves provides both an incentive to preserve the resources and some revenue to accomplish the preservation. Nations harboring rich, biological preserves have begun to realize their value and to extract some of that value from the pharmaceutical industry. The revenue is in part used for inventorying and learning more about the resource as well as preserving it. For example, in 1996, Medichem Research, an Illinois-based pharmaceutical company, entered into a joint venture with the Sarawak government. The organization created by this joint venture has the right to file exclusive patents on two compounds that offer some promise as cancer treatments. The agreement specified a 50–50 split from royalties once the drug is marketed. The Sarawak government was given the exclusive right to supply the latex raw material from which the compounds are derived. Furthermore, Sarawak scientists are involved in screening and isolating the compounds, and Sarawak physicians are involved in the clinical trials. This agreement not only provides a strong rationale for protecting the biological source, but also enables the host country to build its capacity for capturing the value of its biodiversity in the future. These arrangements are particularly significant because they facilitate transboundary sharing of the costs of preservation. It is unrealistic to expect countries harboring these preserves to shoulder the entire cost of preservation when the richer countries of the world are the major beneficiaries.

Box 8.7 illustrates how realistic is the assumption that pharmaceutical demand is sufficient for sufficient preservation while Box 8.8 illustrates the use of Trust Funds for habitat preservation

Box 4.10. Does Pharmaceutical Demand Offer Sufficient Protection to Biodiversity?

Theory suggests that incentives to protect plants are stronger when the plants are valuable to humans. How about practice? The case of Taxol is instructive. Derived from the slow-growing Pacific yew, Taxol is a substance that has been proved effective in treating advanced forms of breast and ovarian cancers. As of 1998, it was the best-selling anticancer drug ever. Since the major site for this tree was in the old-growth forests of the Pacific Northwest, the hope of environmental groups was that the rise in the importance of Taxol might provide both sustainable employment and some protection for old growth forests. In fact, that is not how it worked out. The Taxol for the chemical trials was derived from the bark of the tree. Stripping the tree of its bark killed it. And supplying enough bark for the chemical trials put a tremendous strain on the resource. Ultimately, the private company that marketed Taxol, Bristol-Squibb, developed a semi-synthetic substitute that could be made from imported renewable tree parts. The Pacific yew, the original source of one of the most important medical discoveries in the twentieth century, was left completely unprotected. And the industry that had grown up to supply the bark collapsed. In the end, its value proved transitory and its ability to support a sustainable livelihood in the Pacific Northwest was illusory.

Source: Jordan Goodman and Vivian Walsh. The Story of Taxol: Nature and Politics in the Pursuit of an Anti-Cancer Drug (New York: Cambridge University Press, 2001); Tietenberg and Lewis. P311-312

Box 4.11. Trust Funds for Habitat Preservation

How can local governments finance biodiversity preservation when faced with limited availability of both international and domestic funds? One option being aggressively pursued by the World Wildlife Fund involves trust funds. Trust funds are moneys that are legally restricted to be used for a specific purpose (as opposed to being placed in the general government treasury). They are administered by trustees to assure compliance with the terms of the trust. Most, but not all, trust funds are protected endowments, meaning that the trustees can spend the interest and dividends from the funds, but not the principal. This assures the continuity of funds for an indefinite period. Where does the money come from? Many nations that harbor biodiversity preserves cannot afford to spend the resources necessary to protect them. One possibility is to tap into foreign demands for preservation. In Belize, the revenue comes from a “conservation fee” charged to all arriving foreign visitors. The initial fee, $3.75, was passed by Belize’s parliament in January 1996, raising $500,000 in revenues each year for the trust fund. Similar trust funds have been set up in Mexico, Honduras, and Guatemala. Income from the trust funds can be used for many purposes, including training park rangers, developing biological information, paying the salaries of key personnel, and conducting environmental education programs, depending on the terms of the trust agreement. Biodiversity preservation that depends on funds from the general treasury becomes subject to the vagaries of budgetary pressures. When the competition for funds intensifies, the funds may disappear or be severely diminished. The virtue of a trust fund is that it provides long-term, sustained funding targeted for the protection of biodiversity. In 2004, Belize joined with Mexico, Honduras, and Guatemala to form the Mesoamerican Reef (MAR) fund, a regional financing mechanism. It was created to strengthen the alliance among the four country-specific trust funds. The MAR fund is unique as the first environmental fund in the Western Hemisphere to transcend national boundaries and encompass an entire ecoregion. The fund supports projects related to improving water quality, ecotourism, sustainable fisheries, and strengthening public institutions.

Source: Barry Spergel. “Trust Funds for Conservation,” FEEM Newsletter Vol. 1 (April 1996): 13–16 and the World Wildlife Foundation’s website on conservation trust funds at http://www.worldwildlife.org/what/howwedoit/conservationfinance/conservationtrustfunds2.html (accessed November 18, 2010). Tietenberg and Lewis. P311-312

4.3.2.5 Beyond cost-effectiveness: Political feasibility, social and distributional Issues

Political economists believe that powerful political, economic and security actors fundamentally shape the process of development and state-building by exerting influence and control over institutions of governance, government policies and the distribution of resources. There is now a consensus that this reality needs to be factored into policy and developmental interventions.[24]

[24] Brown & Gra¨vingholt, 2009; John & Putzel, 2009; Department for International Development, 2010, p. 2; Parks & Cole, 2010. See also Oyefusi, A. (2014) Oil Bunkering in Nigeria's Post-amnesty Era: An Ethnopolitical Settlement Analysis. *Ethnopolitics,* Vol. 13, No. 5, 522–545, http://dx.doi.org/10.1080/17449057.2014.931120

Powerful actors in society can easily block a policy or scuttle its implementation if it threatens their interests. In addition to political feasibility is the social and distributional effects of a proposed policy. These considerations may be particularly important in the context of developing countries and are particularly relevant to Sub-Saharan Africa where unemployment and poverty are still major issues. As Zivin and Damon (2012) emphasized, consideration of environmental policy choices must holistically incorporate the ways that choice instruments interact with other political goals if the design is going to be effective and if they are to enjoy widespread support.[25] The authors, showed, for example, that there can be both synergies and the potential conflict between employment and sustainability goals. Of crucial importance is how to manage the joint weights of labor, political, and business interests vested in resource extraction and processing against the long run goal of limiting the idea of employment based on open-access resource harvesting and processing.

As shown in Sahlén and Stage (2012) from a study of Namibia, fiscal reform could help in some settings to address the competing issues of environmental protection and short-term job growth. For example, taxes on fish resources, water, and energy can be directly recycled and put toward employment objectives and income distribution. In particular, the authors found that using fiscal reform revenue to subsidize employment of unskilled labor yield the largest GDP gains (among the alternatives considered) but also had the least attractive environmental outcomes. In contrast, directing revenue toward the poorest households in the form of transfers, rather than in the form of employment subsidies, had the most favorable environmental effects.[26] What the analyses shows is that there is the need for policy instruments to be thoughtfully designed taking account of the context if we are to balance and achieve sustainable development goals.[27]

Summary

- While an understanding of the theoretical benefits of particular economic instruments can be useful, the existing institutional capabilities and environmental policies in the country

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[25] Zivin and Damon (2012), "Environmental Policy and Political Realities: Fisheries Management & Job Creation in the Pacific Islands," Journal of Environment & Development 21(2) 198–218 DOI: 10.1177/1070496512442932

[26] Sahlén and Stage (2012) "Environmental Fiscal Reform in Namibia—A Potential Approach to Reduce Poverty?", Swedish National Institute for Economic Research, Stockholm, https://core.ac.uk/display/36243158

[27] For more on these issues, see Damon and Sterner (2012) "Policy Instruments for Sustainable Development at Rio +20, Journal of Environment & Development 21(2) 143–151.

need to be taken into account in the choice of an effective environmental policy package that will address a given environmental problem.

- Deciding on the most appropriate instruments to address an environmental challenge requires that policymakers must first determine the nature and extent of the problem. In general, environmental problems can only be understood and addressed in the context of the larger economy and society. The state of economic development, cultural values, and population pressures, often constrains the options available to address problems

- The appropriate policy response hinges on a clear and realistic understanding of baseline conditions. Sometimes this may mean a less effective policy on a theoretical basis is actually the most appropriate one, given institutional capabilities

- Given the uniqueness of any given situation, it is difficult to offer specific guidance on how to make policy choices to address environmental problems. However, some general guidelines can help policymakers to choose the most appropriate options for further consideration. These include specifically the recognition of policy trade-offs and realistic assessments of policy limitations.

- Among the various criteria that could be used to evaluate environmental policies, cost effectiveness has been a major focus, both at the theoretical and empirical level. Cost effectiveness relates to achieving a target control level in a manner that minimizes the cost of control.

- Given increasing marginal costs of pollution control, the cost of achieving a given reduction in emissions will be minimized if and only if the marginal costs of control are equalized for all emitters.

- Use of economic instruments, such as emission charges or transferable quotas, rather than CAC instrument such as emission standard, allows regulatory authorities to achieve the cost-effective solution even when they have limited information at their disposal.

- Emission charges not only causes cost-minimizing sources to choose a cost- effective allocation of the control responsibility, it also stimulates the development of newer, cheaper means of controlling emissions, as well as promoting technological progress. However, it has a major drawback in the sense that it is not possible to know ahead the emission charge that will be consistent with the target (desired) level of emission.

- Cap-and-Trade helps to overcome this limitation as it allows the government to meet its policy objective, while allowing greater flexibility in how that objective is met. The incentives created by this system ensure that emission sources use this flexibility to achieve the desired objective at the lowest possible cost.

- Determining the cost-effective level of pollution is more complicated when dealing with nonuniformly mixed surface pollutants. For these pollutants, the policy must be concerned not only with the weight of emissions entering the atmosphere, but also with the location and timing of emissions.

- Since the damage caused by nonuniformly mixed surface pollutants is related to their concentration levels, the search for cost-effective policies for controlling these pollutants focuses on the attainment of ambient standards. Ambient standards are legal ceilings placed on the concentration level of specified pollutants in the air, soil, or water. A cost-effective policy results in the lowest cost allocation of control responsibility consistent with ensuring that the predetermined ambient standards are met at specified locations.

Discussion/Review Questions and Exercises

1. In his book What Price Incentives? Steven Kelman suggests that from an ethical point of view, the use of economic incentives (such as emissions charges or emissions trading) in environmental policy is undesirable. He argues that transforming our mental image of the environment from a sanctified preserve to a marketable commodity has detrimental effects not only on our use of the environment, but also on our attitude toward it. His point is that applying economic incentives to environmental policy weakens and cheapens our traditional values toward the environment.

(a). Consider the effects of economic incentive systems on prices paid by the poor, on employment, and on the speed of compliance with pollution-control laws—as well as the Kelman arguments. Are economic incentive systems more or less ethically justifiable than the traditional regulatory approach?

(b.) Kelman seems to feel that because emissions allowances automatically prevent environmental degradation, they are more ethically desirable than emissions charges. Do you agree? Why or why not?

2. Why do many countries in Sub-Sharan Africa have problems with enforcing environmental control in their extractive industries?

3. Examine the progress in the development and implementation of the United Nations' Reducing Emissions from Deforestation and Forest Degradation (REDD). Do Sub-Saharan African countries stand to benefit from this programme. Why or Why not?

4. How realistic is the assumption that pharmaceutical demand is sufficient for forestry preservation in Sub-Saharan Africa?

5. Two firms can control emissions at the following marginal costs: MC_1= \$200q_1, MC_2= \$100q_2, where q_1 and q_2, are, respectively, the amount of emissions reduced by the first and second firms. Assume that with no control at all, each firm would be emitting 20 units of emissions or a total of 40 units for both firms.

(a). Compute the cost-effective allocation of control responsibility if a total reduction of 21 units of emissions is necessary.

(b). Compute the cost-effective allocation of control responsibility if the ambient standard is 27 ppm, and the transfer coefficients that translate a unit of emissions into a ppm concentration at the receptor are, respectively, a_1= 2.0 and a_2= 1.0.

6. Assume that the control authority wanted to reach its objective in 5(a) by using an emissions charge system.

(a). What per-unit charge should be imposed?

(b). How much revenue would the control authority collect?

7. In a region that must reduce emissions, three polluters currently emit 30 units of emissions. The three firms have the following marginal abatement cost functions that describe how marginal costs vary with the amount of emissions each firm reduces.

Firm Emissions Reduction	Firm 1 Marginal cost	Firm 2 Marginal Cost	Firm 3 Marginal Cost
1	\$1.00	\$1.00	\$2.00
2	\$1.50	\$2.00	\$3.00
3	\$2.00	\$3.00	\$4.00
4	\$2.50	\$4.00	\$5.00
5	\$3.00	\$5.00	\$6.00
6	\$3.50	\$6.00	\$7.00
7	\$4.00	\$7.00	\$8.00
8	\$4.50	\$8.00	\$9.00
9	\$5.00	\$9.00	\$10.00
10	\$5.50	\$10.00	\$11.00

Suppose this region needs to reduce emissions by 14 units and plans to do it using a form of cap-and-trade that auctions allowances off to the highest bidder.

(a). How many allowances will the control authority auction off? Why?

(b). Assuming no market power, how many of the allowances would each firm be expected to buy? Why?

(c) Assuming that demand equals supply, what price would be paid for those allowances? Why?

(d). If the control authority decided to use an emissions tax rather than cap-and-trade, what tax rate would achieve the 14-unit reduction cost-effectively? Why?

Materials used for this section

9. Damon and Sterner (2012) "Policy Instruments for Sustainable Development at Rio +20, Journal of Environment & Development 21(2) 143–151.
10. UNEP (2009): The Use of Economic Instruments for Environmental and Natural Resource Management First Edition.
11. Titenberg, T. & Lewis, L. (2012). Environmental & Natural Resource Economics 9th Edition, The Pearson Series in Economics
12. Sterner, T. and J. Coria (2012). Policy Instruments for Environmental and Natural Resource Management. Resources for the Future.

Module 4.4. Application to Sub-Saharan Africa (1 hour)

Sub-Saharan African countries faces many environmental challenges, including urban pollution, over-exploitation of renewable resources, such as fisheries; deforestation, and loss of biodiversity. The peculiar characteristics of most of these countries (high and increasing population, high rate of rural-urban migration, dependence on natural resources for sources of livelihood and government revenue, monocultural nature of the economy, high levels of poverty, poor service delivery, and weak institutional arrangements among others) complicates these problems. Understanding these baseline conditions is crucial to developing policies to address the environmental challenges in the continent.

For example, many countries depend on the extractive sector for government revenue and foreign earnings. Activities in this sector often generate environmental problems, thus imposing damages on communities and huge costs on residents. In many cases, the problem is not the absence of environmental laws but the political will and technical capacity to enforce them.

An associated issue is earmarking environmental tax revenues for environmental purposes. This may be a controversial issue, especially in developing countries were public funds are often scarce and corruption levels are high. If the environmental tax itself gives enough incentive to reduce pollution or resource overuse sufficiently, the tax benefits may be diverted to the general treasury. If on the other hand, the tax does not give enough incentive to fully solve the environmental problem (which is often the case), it may be argued that tax revenues should be earmarked for environmental purposes such as publicly-financed abatement (e.g. sewage treatment). Another consideration in this direction will be how to compensate the direct victims of environmental degradation.

An important question to ask is what is the relative importance of Command-and-Control policy instruments compared to market-based instruments, in the context of Sub-Saharan Africa. Put differently, how far can reforms aimed at promoting the use of market-based instruments to solve environmental problems go? Can Sub-Saharan African countries use the experience of the industrialized countries to move directly into using market-based instruments to control environmental problems? The debate in Box 4.12 shows that the answers to these questions are not as straight-forward. Coria and Sterner (2010, 2011), and Damon and Sterner (2012) examine the same issue in the broad sense of whether developing countries have the administrative capacity to deal with complex environmental policy instruments. In their view, many developing countries simply need to develop this capacity just the same way they need to develop many basic government functions such as tax systems, public expenditure, social security, etc. While striving for instruments that are simple and transparent, such as taxes on fossil fuels, is of first-order importance, these instruments are in many cases, inadequate. According to the authors, the tradeoffs between better governance with environmental instruments and the risk that such instruments may pose in terms of sophisticated management, as well as risks posed by rent seeking, need to be managed cautiously from case to case. What is evident overall is that many

Box 4.12. Should developing Countries rely on Market-based Instruments to Control Pollution?

Since the case for using market-based instruments seems so strong in principle, some observers, most prominently the World Bank (2000), have suggested that developing countries should capitalize on the experience of the industrialized countries to move directly to market-based instruments to control pollution. The desirability of this strategy is seen as flowing from the level of poverty in developing countries; abating pollution in the least expensive manner would seem especially important to poorer nations. Furthermore, since developing countries are frequently also starved for revenue, revenue-generating instruments (such as emissions charges or auctioned allowances) would seem especially useful. Proponents also point out that a number of developing countries already use market-based instruments. Another school of thought (e.g., Russell and Vaughan, 2003) suggests that the differences in infrastructure between the developing and industrialized countries make the transfer of lessons from one context to another fraught with peril. To illustrate their more general point, they note that the effectiveness of market-based instruments presumes an effective monitoring and enforcement system, something that is frequently not present in developing countries. In its absence, the superiority of market-based instruments is much less obvious. Some middle ground is clearly emerging. Russell and Vaughan do not argue that market-based instruments should never be used in developing countries, but rather that they may not be as universally appropriate as the most enthusiastic proponents seem to suggest. They see themselves as telling a cautionary tale. And proponents are certainly beginning to see the crucial importance of infrastructure. Recognizing that some developing countries may be much better suited (by virtue of their infrastructure) to implement market-based systems than others, proponents are beginning to see capacity building as a logical prior step for those countries that need it. For market-based instruments, as well as for other aspects of life, if it looks too good to be true, it probably is. Source: World Bank. Greening Industry: New Roles for Communities, Markets and Governments (Washington, DC: World Bank and Oxford University Press, 2000); and Clifford S. Russell and William J. Vaughan. "The Choice of Pollution Control Policy Instruments in Developing Countries: Arguments, Evidence and Suggestions," in Henk Folmer and Tom Tietenberg, eds. The International Yearbook of Environmental and Resource Economics 2003/2004 (Cheltenham, UK: Edward Elgar, 2003): 331–371.

countries, and even more so Sub-Saharan African countries, need more capacity building in the area of environmental management. Also vital is the urgent need for more pragmatic instruments that can be adopted in the face of many deeply connected goals, complications, and political realities.

The previous Moules on this topic (Modules 4.1 through 4.3) have raised questions that can be directly applied in case studies of countries in Sub-Saharan Africa. The reader from the Continent may be interested in identifying the main environmental challenges in his/her community/country and what is the role of economics in addressing them; in particular, what control policy will be most effective. Finally, ecotourism is an emerging trend in Sub-Sharan Africa. It will be revealing to examine the progress being made in this direction through some case studies, for example, a study of the Eco-tourism Society of Kenya (ESOK). Of relevance also will be a focus on the prospects for the use of information systems as a policy instrument in the sector.

Materials used for this section

1. Damon and Sterner (2012) “Policy Instruments for Sustainable Development at Rio +20, Journal of Environment & Development 21(2) 143–151.
2. UNEP (2009): The Use of Economic Instruments for Environmental and Natural Resource Management First Edition.
3. Sterner, T. and J. Coria (2012). Policy Instruments for Environmental and Natural Resource Management. Resources for the Future.

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Thank you.

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