ENVIRONMENTAL POLICY[1]

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INTRODUCTION

When economic activity leads to pollution and over-use of common property resources, government intervention can improve social welfare. Pollution involves a market failure in which damages caused by a producer or consumer are imposed on third parties. These damages can involve personal health, physical deterioration of buildings, and foregone options for the future. Of course, if transactions costs are low, those causing pollution damages could be taken to court if the liability rules are clear. Common property resources present similar problems, such as losing unique ecological habitats, endangering particular species, or destroying valued scenic vistas. Since there may not be clear property rights to such elements of the environment, these common property resources can be overutilized. Identifying the pollution sources and determining the extent of the environmental protection can be problematic, so environmental laws are generally passed to address these market failures. In both cases, determining the benefits and costs of alternative policies can be a contentious exercise.

Environmental economics is the study of how economic and environmental issues interact, including evaluating ways to reduce pollution and analyzing nonrenewable resources. No single field of study contains all the insights needed to develop and implement sound environmental policies. However, the focus here will be on economics because it provides a framework for incorporating many perspectives. Depending on the burden of proof, the resulting policies might be excessively stringent (costly relative to their benefits) or the policies may be inadequate for the protection and preservation of environmental features that affect human health and welfare or have intrinsic value.

We know from materials balance that human activity does not create matter but only changes its form, concentration, and location. While all societies affect natural systems, the scale of potential impacts has grown with economic development. There is evidence that as incomes rise, citizens are willing to devote relatively more resources to controlling environmental impacts. However, many would like to see much more attention given to reducing current damages and limiting the risks for future harm.

[1] Draft prepared for the *Encyclopedia of Energy Engineering*

MULTIDISCIPLINARY PERSPECTIVES

The development and implementation of sound environmental policy requires a number of steps:

(1) Determine appropriate regulatory objectives (through citizen participation in political processes and community consensus-building);
(2) Balance those objectives to determine regulatory priorities;
(3) Identify and legislate oversight responsibilities for environmental agencies;
(4) Develop (a) mechanisms for monitoring ambient air and water quality and (b) methodologies for integrating new scientific understandings of environmental impacts into the policy prioritization process;
(5) Define the appropriate targets for different types of pollutants and the protection of biodiversity;
(6) Analyze environmental indictors on a regular basis, checking for noncompliance;
(7) Evaluate impacts, recognizing potential biases in the measures and the ways impacts are valued;
(8) Determine (and then apply) the appropriate policies for meeting objectives; and
(9) Establish an effective process for monitoring and reviewing the framework, including the penalties and sanctions applied when there is noncompliance.

These steps require input from a number of disciplines that shape the way we see things. Although technical training allows analysts to delve deeply into subjects in a consistent manner, awareness of other disciplines' perspectives can be important for constructive environmental policy making.

- *Engineers* look to technologies for solutions to environmental problems. They are able to incorporate new (often expensive) control technologies into energy extraction, production, consumption (energy efficiency), and pollutant disposal and storage (as with nuclear waste).
- *Meteorologists* and *Hydrologists* analyze pollution transport in air and water systems. They have a deep understanding of the impacts of discharges under different conditions. In conjunction with *Demographers and epidemiologists,* they can estimate the doses received by different population groups.
- *Medical scientists* and *toxicologists* analyze the dose-response relationships for citizen health, conducting exposure and risk assessments.
- *Ecologists* study the impacts of pollutants on the local and global environment, assess the value of ecosystem services, and track invasive species and biodiversity. *Climate scientists* help assess the causes and consequences of changes in local and global temperatures and other weather patterns.
- *Materials scientists* look at damages caused by air and water pollution. The associated impacts include cleaning and painting buildings, treatment costs, and shorter life-spans for affected equipment.
- *Political scientists* focus on issues of power, legitimacy, social cohesion, and the roles of different stakeholder groups in influencing environmental policies.

Consensus is critical because ultimately, in a democratic system, there needs to be widespread agreement on desired outcomes if the system is to avoid instability.

- *Economists* emphasize the importance of efficiency in resource allocation. They apply benefit-cost analysis and tend to depend on price signals to provide incentives for the adoption of appropriate control technologies and conservation measures.
- *Planners* deal with land use and zoning issues, given population growth projections. Planners integrate legal constraints with historical experience; bringing topological, aesthetic, and geographical elements to the analysis.
- *Archeologists* and *anthropologists* provide insights on the impacts of dams, mines, and related economic activities on unique historical sites, local populations, and indigenous groups. Such impacts create difficult valuation issues (1, 2).
- *Lawyers* spotlight the institutions of policy implementation. For example, rules and regulations attempt to pay significant attention to procedural fairness. Due process contributes to the legitimacy of outcomes. If the different parties perceive that there is no transparency nor opportunities for participation, environmental policy will be perceived as unreasonable; the laws will either be changed or they will be disobeyed in a variety of ways.
- *Environmentalists* advocate sustainability and environmental equity. The by-products of energy production affect public health and have environmental outcomes. Those impacts have economic value, but often that value is non-monetary or difficult to quantify. For example, generation and transmission siting decisions incorporate impacts on biodiversity and sustainability.
- *Ethicists* help us understand our personal values and notions of stewardship. We have a clear responsibility to leave future generations with a legacy of sound institutions and a clean environment, though the best means to this end are often not obvious.

Thus, physical, biological, and social scientists attempt to uncover patterns and identify lessons to help us improve policy. Given the complexity of environmental issues, most environmental problems are managed, not solved.

IMPACTS

Energy production and consumption impact people and the environment in a number of ways. Emissions can be from a single point or mobile source. Emissions can be continuous or intermittent (with exposure and impacts depending on the wind and other weather conditions and/or the presence of other chemicals). The transport mechanism can be complicated and involve multiple jurisdictions (as with SO_2 leading to “acid rain” in affected states).

Air: Issues range from local concentrations of particulate matter in the atmosphere to concerns over anthropogenic climate change. Consequences for health, ecosystems, agriculture, coastal settlements, species survival, and other impacts make atmospheric change a serious policy issue. For example, long range transport means pollutants and greenhouse gases cross international boundaries—requiring international coordination.

Water: Effects of contaminants vary in surface waters and groundwater. The U.S. has primary standards to protect the public health (with maximum contamination levels[MCLs] for toxic wastes). Secondary standards, and associated MCLs, are meant to protect the public welfare (for example, ensuring that the taste, odor, and appearance of groundwater do not result in persons discontinuing water use). Other environmental issues include species loss and dealing with nonindigenous, invasive species.

Land Use: Siting is an issue for electricity generators, transmission lines, and distribution systems.[2] The problem of NIMBY (Not In My Back Yard) is universal: we like the convenience of electricity but do not want its production or transport to affect our own property. Surface coal mines are an eyesore, but restoration can be costly. Hydroelectric dams can affect fisheries, flood unique canyons (causing a loss of scenic vistas), damage ecosystems (as in the Amazon), or displace human populations (as with China's Four Gorges Project). Solar collection stations and wind generators take space and have impacts on aesthetics. For some, viewing large windmills along the crest of a lovely mountain range is an eyesore. For others, the same scene is a symbol of hope.

Sometimes, reducing discharges in one area (say, air), increases impacts in another (water). For example, reducing CO_2 emissions through greater use of nuclear energy reduces greenhouse gases but raises issues of waste storage and protection.

BURDEN OF PROOF

Because environmental issues tend to be complex, delays in responding to citizen concerns and new scientific information can lead to negative impacts or a local crisis. What is more problematic: erring on the side of environmental protection or erring on the side of development? When the science is unclear or studies yield conflicting outcomes, the issue of burden of proof arises. Two types of errors are possible. In a Type I error, a hypothesis is rejected when it is in fact true (e.g., deciding that a pollutant causes no health damages when in fact it does). Rejecting the hypothesis of a health link would lead to more emissions (and citizen exposure) than otherwise would be the case.

A Type II error occurs when the decision maker fails to reject a hypothesis that is in fact false (e.g., not rejecting the hypothesis that low doses of a pollutant have no damaging side-effects for certain types of citizens, such as asthmatics, who are viewed as potentially sensitive to a particular pollutant). If in fact, at low doses, the pollutant does not have negative health impacts, environmental regulators might have imposed compliance strategies that were costly based on the Type II error. Dose-response models that do not reject linear functions when the actual relationships are non-linear would fall into this category.

[2] Other aspects of land use include urban sprawl and availability of land for agriculture. The focus here is on the environmental impact of energy systems. For example, social investments in mass transit affect emissions from mobile sources (autos). However, environmental policy addresses many other issues, such as the use of pesticides and fertilizers by agriculture, or deforestation.

Both types of errors have costs. It can be argued that environmental regulators will tend to avoid making Type I errors. When evidence accumulates and shows conclusively that a pollutant has health impacts, those responsible for environmental policy do not want to be blamed for acting too slowly. Furthermore, citizens might prefer excessive caution (labeled a "precautionary bias"). On the other hand, Type II errors can result in regulators imposing high abatement costs onto polluters (and those purchasing associated products) in a manner that is not cost effective.

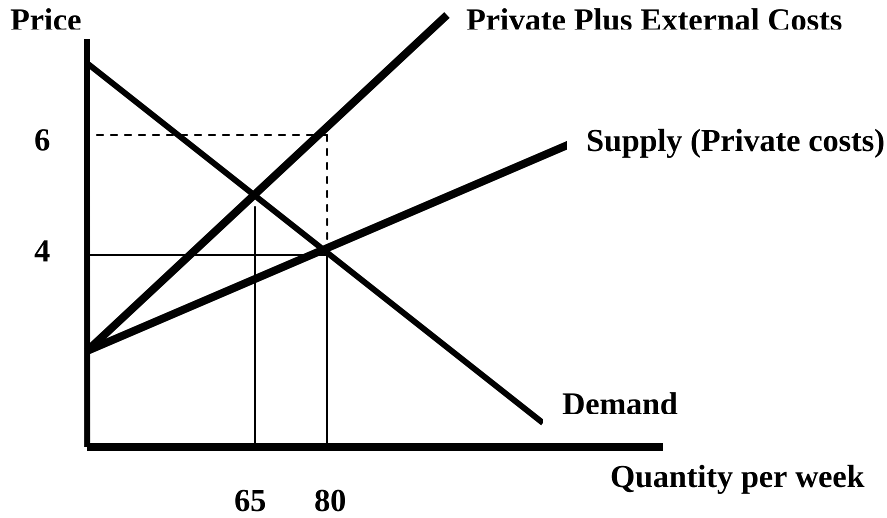
A related issue is whether or not the environmental impact is irreversible. If it is not reversible, a case can be made that the burden of proof should be assigned to those who assert that relatively higher levels of pollution are not problematic. On the other hand, if abatement costs are systematically underestimated and the benefits of pollution reduction are overestimated, it is possible to devote excessive resources to limiting environmental impacts.

ECONOMIC FRAMEWORK

Economists are aware that it is difficult to place monetary values on many impacts of pollution, but argue that environmental amenities must be balanced against other valued goods and services (3). Some view economists as over-emphasizing the efficacy of market incentives, to the exclusion of other instruments. However, because it offers a consistent framework for integrating insights from other fields, it will be described here.

Cost-Benefit Analysis (CBA): The most fundamental economic analysis looks at how pollution impacts (reflected in "external costs") cause excessive consumption of polluting goods in the absence of government intervention. These external costs are the negative spillover effects of production or consumption for which no compensation is paid (e.g., a polluted stream that damages the health of those living along the stream). Producers consider the environment to be a free input, hence they only minimize private costs. If these external costs are added to the private costs (reflected in the supply curve) we get the total social costs.

Figure 1: Private Costs and External Costs

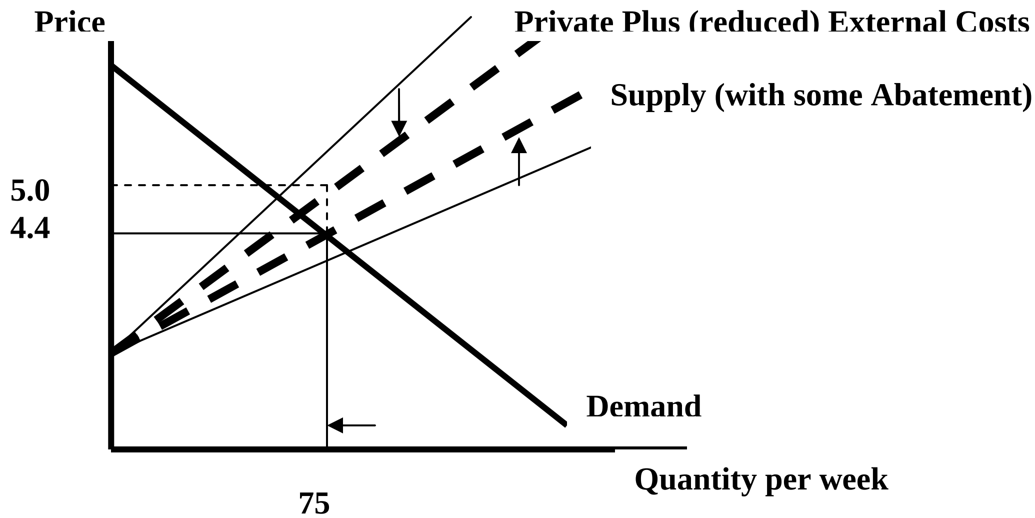


[Insert Figure 1]

Figure 1 shows how a competitive product market yields an equilibrium price ($4) and quantity (80 units per week). However, in the absence of public intervention, the price only reflects the private costs of production, not damages imposed on others (amounting to $2 when the 80^{th} unit is produced—but assumed to be less if only 65 units of the good are produced. The external costs are higher at higher levels of output, presumably because damages rise dramatically when there are very high concentrations of the pollutant in the atmosphere). Determining the extent of those damages requires some valuation metric.

For now, let us assume that the analysts "got it right" for estimating both benefits and costs. This is a strong assumption, since environmental services are notoriously hard to price. This problem can limit the ultimate effectiveness of CBA because the abatement costs tend to be short-term and quantifiable, but the benefits (avoided damages) are often long-term and/or difficult to quantify. For now, consider the impacts of environmental regulation within the CBA framework. Regulation requires pollution abatement activity, raising production costs but reducing the pollution and associated damages (as shown in Figure 2).

Figure 2: Reducing External Costs

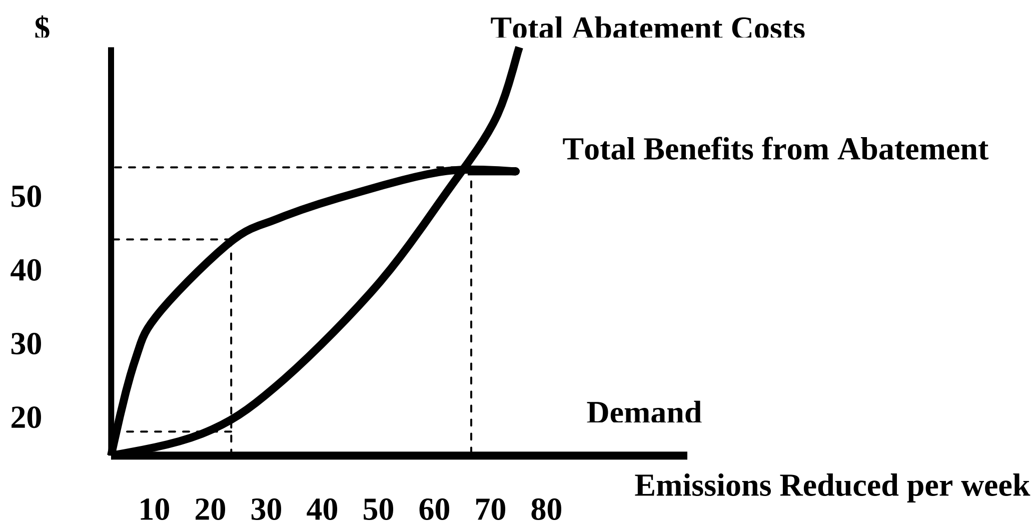


[Insert Figure 2]

The imposition of environmental regulation raises production costs (shifting the supply curve up) and reduces equilibrium consumption of the polluting good (from 80 per week to 75 per week) because price has risen (from $4 to $4.40). In addition, external costs are reduced (so the sum of private and external costs is now $5 when 75 units of the good are produced). Emissions are reduced (though this particular figure only indicates the reduction in damages, not the precise reduction in emissions).

The next question is how much pollution abatement makes economic sense, since control costs rise rapidly as emissions are cut back towards zero. Continuing with our illustrative example, Figure 3 depicts the total benefits of abatement and total cost of abatement. The latter depends on the abatement technology and input prices and the interdependencies among production processes (for retrofitting control technologies). It is relatively easy to compute abatement costs from engineering cost studies, although predicting future control costs is not easy since innovations will create new control technologies. The benefits from abatement (or the reduction of pollution damages—the cost of pollution) depend on the size of the affected population, incomes (indicating an ability to pay for environmental amenities), and citizen preferences (reflecting a willingness to pay). The benefits can be very difficult to estimate: consider, for example, health benefits of reduced particulates in the atmosphere, habitat values, and citizen valuations of maintaining a habitat for a particular species. Physical benefits can be found from dose-response studies. Various survey methods and market proxies for computing the willingness to pay to avoid experiencing the impacts of pollution have methodological problems. However, if the dollar metric is to be used for determining the benefits of environmental improvements, techniques can at least establish rough benchmarks (as shown in Figure 3).[3]

Figure 3: Total Benefits and Total Cost of Abatement

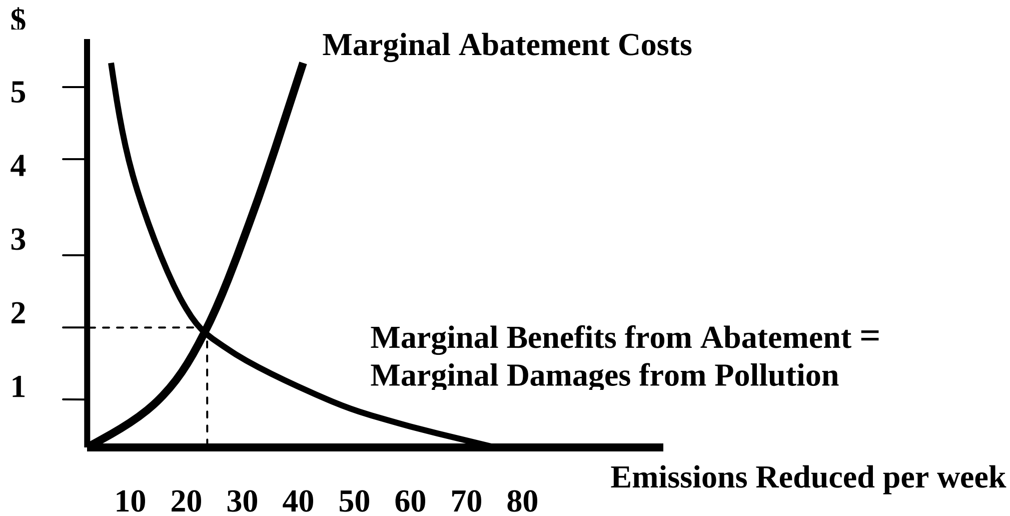


[Insert Figure 3]

We can relate the total benefits and costs to the marginal benefits and costs since, for economists, the issue is not zero emissions vs. unlimited emissions. In the former situation, if 80 units of the good results in 80 tons of emissions, then zero emissions reduced would be characterized as having no abatement costs (but also, no benefits from abatement). When total benefits equal total cost of abatement (at 65 tons of emissions reduced per week in Figure 3), the last reductions in emissions were very costly, and the additional benefits fairly small. Zero abatement activity would also be inefficient in this example because the marginal damages are very high, and marginal abatement costs are quite low. Economics tries to determine the optimal amount of emissions. In the hypothetical example, the "optimal" quantity of reduced emissions is about 25, where the marginal abatement cost is just equal to the marginal benefits of $2. These are depicted in Figure 4:

[3] Some argue strongly against the use of cost-benefit analysis. (4)

Figure 4: Marginal Benefits and Marginal Cost of Abatement



[Insert Figure 4]

This outcome means that there are still 55 tons of emissions per week. If the estimated benefits and costs of pollution abatement are correct in this illustration, economic efficiency would be violated if additional resources were devoted to abatement activity: for example, if 50 tons of emissions were reduced (so only 30 tons of the pollutant are released), the marginal benefit would be about $1, but the marginal cost would be greater than $5. From the standpoint of economic efficiency, those resources could be used to create greater value in other activities.

Of course, the difficulty of obtaining a common dollar metric for all the impacts of different pollutants means that benefit-cost analysis must incorporate a range of values. The range could be incorporated in Figure 4 as a band around the marginal benefit curve indicating one standard deviation from the calculated values. A conservative approach would recognize that the marginal benefit function could be above that depicted in Figure 4—which would lead to optimal emission reduction of more than 25 tons per week (improving the ambient air quality).

Further complicating the analysis are production and exposure interdependencies. For example, the marginal cost of abatement associated with one type of emission may depend on the level of treatment (or abatement) for another contaminant. A joint optimization problem results, with the basic principles unchanged. Many investments in abatement equipment have this characteristic: once one set of contaminants is being reduced from a discharge flow, the cost of dealing with additional contaminants can be relatively low. For example, in the case of water discharges, if iron or manganese is removed via the precipitation method, TDS (total dissolved solids) is reduced and there may be an improvement in water clarity.

Interdependencies can also arise on the benefit side when the dose-response relationship for a particular contaminant is influenced by the presence of other contaminants. Again, in the case of secondary groundwater standards, perceptions of odor and color will be affected by whether they occur in combination. Such considerations must be factored into the analysis when comparing the benefits and costs of different treatment options.

SPECIFIC POLICIES

In the United States, the Water Pollution Control Act of 1956 and the Clean Air Act of 1963 and subsequent amendments to both pieces of legislation have focused on achieving ambient standards. The U.S. Environmental Protection Agency is responsible for implementing these laws, just as in other nations where agencies have been established to reduce emissions and improve environmental outcomes. A number of policy options can lead to emission reductions (5, 6).

Tax on the polluting good: An excise tax could be imposed on the good, cutting back consumption to 65 units per week. Of course, the problem is not with the product, but with the emissions associated with its production. Thus, this option does not provide incentives for developing new technologies that reduce abatement costs.

Tax on emissions: A penalty or charge for each ton of emissions would lead suppliers to cut back on emissions—to the extent that the abatement is less expensive than the tax. Thus, in Figure 4, a tax of $2 per ton would lead to the optimal reduction of pollutants. In addition, it provides incentives for innovation in the control technology industry. Firms will seek ways to reduce abatement costs, reducing their pollution taxes. This strategy is likely to be fought by polluters who will be passing on the taxes to customers (where the ultimate incidence depends on supply and demand elasticities).

Tradable emissions permits: The same result (and incentives) is obtained if "allowances" of 25 tons are allocated to polluting firms—limiting emissions.[4] This approach provides an incentive for those with low abatement costs to reduce emissions and sell their permits (allowances) to others whose abatement costs would be very high. This places entrants at a disadvantage since incumbent firms are "given" these valuable allowances. The SO_2 regime in the United States has this feature: of course, the initial allocations can be a political nightmare. In establishing a tradable permit regime, an environmental agency must determine the allowed level of emissions (here, 25 tons) and whether additional constraints might be applied to local areas with particular circumstances. In addition, the energy sector regulator has to make decisions regarding the treatment of cost savings from the regime. For example, savings might be passed on to consumers or retained by firms. The latter situation provides an incentive for utilities to participate in the emissions trade markets. Some sharing plan could also be utilized so

[4] The situation is not completely identical: a tax has certain costs to firms but yields uncertain overall abatement because regulators will not have precise estimates of abatement costs; the allowances have certainty in terms of overall abatement but uncertain cost. Of course, with monitoring, the tax can be varied over time to achieve a desired ambient condition.

customers benefit as well.

Tighten liability rules: An alternative approach would utilize a court-based system, where fees would be assessed against those responsible for damaging the health of others, for reducing the economic value of assets, or for reducing the amenity values of ecosystems. Of course, this approach requires a well-specified set of property rights and clear causal links between specific emitters and affected parties. The transactions costs of such a system (resources devoted to negotiations and legal activity) could be prohibitive for many types of pollutants.

Emission reduction mandates: Although equal percentage cutbacks sound "fair," this strategy is not cost-effective, since abatement costs can differ widely across pollution sources. If there are scale economies to emission reduction, it would be most efficient to have a few firms reduce emissions. The least-cost way to achieve a given overall reduction in emissions will involve differential cutbacks from different firms.

Mandate a specific control technology: This "command and control" strategy is not cost-effective, since production conditions and retrofitting production processes differ across firms (based on age of the plant and other factors). However, this policy option has been utilized in a number of situations, as a "technology-forcing" strategy.

OTHER POLICY ISSUES

The above instruments have been utilized in different circumstances. A further set of issues involves intrinsic benefits, cost-effectiveness, income distribution, sustainability, and renewable resources.

Intrinsic or nonuse benefits: Some people take a more expansive view of environmental amenities as they attempt to separate economic values from inherent values. However, the latter might be partly accounted for in terms of the perceived benefits to future generations. Intrinsic benefits from environmental programs include option values, existence values, and bequest values (7). The first value represents a form of insurance so future access to a potential resource is not eliminated due to current consumption. The rationale behind option value is closely related to the "margin for error" argument noted earlier. Existence value reflects a willingness to pay for the knowledge that the amount of contaminant in the environment does not exceed particular levels or that a particular species (or level of biodiversity) is retained. The resource or ecological system is available for others. The bequest value can be interpreted as the willingness to pay for preserving a resource (or a geographic site) for future generations.

Cost effectiveness analysis: Instead of trying to estimate the dollar benefits (of say, saving a human life or reducing the incidence of asthmatic attacks), one can compare the number of lives saved per dollar spent in abatement activity across programs. Thus, cost-effectiveness analysis involves finding the least-cost method of achieving a given economic or social objective, such as saving lives or retaining unique ecological settings. No dollar value (or explicit measure of avoided damages) is placed on that objective (8).

Redistributive effects: It is important to note that those citizens being harmed by emissions are not necessarily the same as those who are consuming the polluting good (such as electricity). Even if a particular program has positive net benefits, some parties are likely to be losers. They are seldom compensated and left better off, raising concerns about the distributional consequences of alternative policies. Furthermore, those harmed may have lower incomes (and thus, lower willingness to pay to avoid damages due to lower ability to pay). This point underscores the role of fairness as a factor that might outweigh efficiency considerations in some circumstances. Some agencies have been forbidden to use CBA on the grounds that the numbers are too speculative and that social concerns should be given priority. Intergenerational concerns can be interpreted as reflecting redistributive considerations.

Sustainable development: Some of the issues associated with energy involve the use of non-renewable resources (irreversibility). Some citizens argue that sustainability requires development that can be supported by the environment into the future. These people wish to ensure that resources are not depleted or permanently damaged. However, since sustainability depends on technology, and innovations change resource constraints, defining the term with precision is quite difficult.

Renewable energy resources: Generating electricity without fossil fuels (e.g., hydro, wind, solar, biomass) is sometimes referred to as using green options. Green options are often limited in the amount (and reliability) of energy produced in a given time period. Utility applications for renewable resources include bulk electricity generation, on-site electricity generation, distributed electricity generation, and non-grid-connected generation. Demand reduction through energy-efficient technologies is a substitute for energy, whatever the source.

CONCLUSIONS

The three main trends in environmental regulation in recent years have been shifting from command-and-control regulation toward greater use of economic instruments (such as emissions trading), seeking more complete information on the monetary value of environmental costs and benefits, and a tendency for addressing environmental objectives in international meetings, as with the Kyoto Protocol (9).

The interactions between economic and environmental regulation raise important policy issues. If energy sector regulation and environmental regulation remain separate, some means of harmonization may be necessary to promote improved performance. Collaboration would involve clarifying the economic duties of the environmental regulator and the environmental duties of the economic regulator. To avoid regulatory competition, agencies sometimes establish task forces or other mechanisms for identifying and resolving issues that might arise between jurisdictional boundaries (across states or between state and federal authorities). Such cooperation can serve to clarify the division of responsibilities and identify regulatory instruments that will most effectively meet economic and social objectives.

In summary, policy makers respond to domestic political pressures by devising institutions and instruments to address pollution and environmental sustainability (10). Although no single field of study contains all the tools necessary for sound policy formulation, economics does provide a comprehensive framework for evaluating the strengths and limitations of alternative policy options. Because of the pressures brought to bear by powerful stakeholders, adopted policies and mechanisms are not necessarily cost minimizing. The resulting inefficiencies may partly be due to considerations of fairness, which places constraints on whether, when, how and where environmental impacts are addressed. As is emphasized in this survey, citizens want to be good stewards of the land. We appreciate the adage: "The land was not given to us by our parents; it is on loan to us from our children." How to be good stewards—through the development and implementation of sound environmental policies—has no simple answer given the complexity of the issues that need to be addressed.

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