POLICY INSTRUMENTS FOR POLLUTION CONTROL IN DEVELOPING COUNTRIES

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What are appropriate strategies for protecting the environment in developing countries that also seek to promote growth and reduce poverty? This article reviews the literature on cost-effective intervention, comparing regulatory and fiscal instruments that can be attuned to the purpose of reducing pollution. The authors look at what happens when developing country ingredients are introduced into the standard policy problem, and show how indirect instruments can be effective when monitoring and enforcement are costly. They discuss distributive concerns for two reasons: the effect on the poor may need particular consideration for equity reasons, and the effect on groups with vested interests can determine whether reforms are likely to stand or fall.

Rigorous studies of pollution control in developing countries do not exist, but there is convincing casual evidence that regulations to protect the environment are ineffective or unnecessarily costly. Often, there are no regulations or they are badly designed or enforced (see Bernstein 1991). In addition, economic policies seemingly unrelated to the environment—subsidies for water consumption, pesticides, fertilizers, and energy use—nevertheless affect it, often for the worse (Schramm and Warford 1989). Evidence on the damage that pollution is doing to human health and productivity is starting to accumulate (see Thomas 1981 and 1985 on São Paulo; Hertzman 1990 on Poland; Margulis 1992 on Mexico).

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This article reviews the design of cost-effective interventions to protect the environment from excessive pollution in developing countries. The focus is deliberately limited to domestic policies to control pollution. We do not treat policies to address other environmental problems, such as soil erosion, deforestation, biodiversity, or desertification; nor do we deal explicitly with transnational problems (acid rain) or the global consequences of pollution (climate change; ozone depletion). Many of the principles we present, however, relate broadly to correcting for externalities, or spillover effects, and can be applied to these other problems as well (see Binswanger 1989; Mahar 1989; Repetto and Gillis 1988; Schramm and Warford 1989).

The analysis concentrates on policy instruments that have traditionally been in the realm of public finance, such as taxes, prices, and subsidies, comparing these with regulations and other instruments traditionally used to reduce pollution or ameliorate its damage. The interventions can be categorized as (a) market-based incentives (MBIs) that affect the incentives of private agents, (b) command and control (CAC) instruments that regulate activity through constraints on the source of pollution, and (c) government spending on cleanup or enforcement (table 1). In this article we focus on (a) and (b), because the principles guiding the decisions regarding (c) are fairly well established in the cost-benefit literature. We also distinguish between instruments directly associated with the amount of damage created or pollutants emitted, and those addressing pollution indirectly via related variables such as inputs and outputs.

The analysis begins by examining the rationale for government intervention and goes on to look at the relative merits of the policy instruments traditionally prescribed for that intervention in industrial countries. The arguments for these standard policy prescriptions are based on several simplifying assumptions—

Table 1. *A Taxonomy of Policy Instruments to Reduce Pollution*

Policies	*Direct instruments*	*Indirect instruments*
Market-based incentives	Effluent charges; tradable permits; deposit refund systems	Input/output taxes and subsidies; subsidies for substitutes and abatement inputs
Command and control measures	Emission regulations (source-specific, nontransferable quotas)	Regulation of equipment, processes, inputs, and outputs
Government production or expenditure	Regulatory agency expenditures for purification, cleanup, waste disposal, and enforcement	Development of "clean" technologies

competitive markets, costless transfers, certainty, full information. These assumptions may be less applicable in developing countries. The remainder of the article investigates what happens to policy prescription when the standard assumptions are relaxed to take conditions in developing countries into account.

The Rationale for Government Intervention

The efficiency argument for public intervention to mitigate pollution problems is well established in the theoretical literature (see Baumol and Oates 1979, 1988; Tietenberg 1988b). Pollution is an example of a negative external effect; it imposes harmful effects and costs on people other than the polluters. The free market offers the polluters no inducement to reduce the damage, since the costs are largely paid by others. The market, if left to itself, is consequently not the most effective mechanism for keeping pollution at reasonable levels. Optimal control of pollution would occur if the marginal costs, including damages from pollution, were low enough to be balanced by the marginal benefits from the activity.

Is public intervention in fact essential to correct for such externalities? According to Coase (1960), there is no efficiency reason for a government to be involved except to help enforce property rights. Coase's proposition is that if those affected by pollution hold the rights to an unpolluted environment, polluters will "bribe" them to allow some level of pollution. (Member states of the Organization for Economic Cooperation and Development [OECD] and many other countries have, in principle, given property rights to victims through the "polluter pays" principle.) Similarly, if polluters have the right to pollute, victims will bribe them to pollute less. In either case, as long as negotiations are not costly, the resulting amount of pollution would be optimal.

When polluters and victims are few and the number of beneficiaries from an agreement is fixed, the Coase proposition may indeed be valid: negotiations can provide for the internalization of externalities. Such a negotiated solution seems feasible in a situation such as in the Philippines, where soil sediments caused by a single logger threatened the development of tourism in a bay (Dixon and Hodgson 1988). When rivers run from one jurisdiction to another (as the Paraíba does between São Paulo and Rio de Janeiro), the parties involved are easily identified, and they could agree on pollution loads through negotiation. In Turkey, farmers have been awarded damages in court when emissions from factories have hurt their crops; here the established right to an unpolluted environment did provide incentives to abate. Thus, when stakeholders are easily identified and law enforcement is assured, a case can be made that government intervention is unnecessary for efficient outcomes.

But, for the Coase proposition to hold, the costs of negotiating and enforcing agreements must be zero or negligible. In practice, the costs will increase with the number of polluters and victims. In Mexico City, for example, there are

20 million consumers, 2.5 million motor vehicles, and 30,000 industries; it seems hardly feasible that the economic agents concerned will conduct efficient negotiations without an intervening authority. In private negotiation, parties have an incentive to free-ride, either by not revealing willingness to pay or by breaking the agreement. Moreover, to be efficient in the long run, the agreement must accommodate the entry of newcomers into the market and the exit of others.[1] Public intervention will often be the only efficient solution to these coordination problems.

Standard Policy Prescriptions

Given that intervention is required, what form should it take? Policies aim either to regulate the level of pollution at the source or to change prices or regulations to increase the private costs of polluting. To facilitate comparison, discussion of the standard policy instruments that follows starts out with some restrictive assumptions: (a) pollution is uniformly dispersed—that is, the external costs to society are independent of the location of the source; (b) transferring revenue to or from the public sector is not in itself costly; (c) the costs of monitoring damage and emissions are low; (d) there is no uncertainty about the costs and benefits of pollution control; and (e) a competitive market structure prevails. Toward the end of this section we refine the comparison of instruments by relaxing the first assumption—uniform dispersion. The subsequent section will relate the argument to developing country conditions by relaxing each of the remaining assumptions in turn and adding the issue of distributive objectives.

Uniform Dispersion of Pollutants

When pollutants are uniformly dispersed, ambient quality can be improved or protected only by curbing emissions overall. Command and control policies constrain emissions from each source and do not allow sources to trade the right to pollute. Most industrial countries have relied predominantly on CAC methods, setting and enforcing standards for equipment, processes, or emissions (Opschoor and Vos 1989; Bernstein 1991). Emerging experience from developing countries does not appear to break this trend. With market-based incentives, by contrast, constraints are not source-specific; they provide equal incentives to all by increasing the marginal costs of polluting. Tradable permits, subsidies for abatement, and emission taxes are examples of such instruments. All let the market distribute abatement to where it is cheapest.

CAC VERSUS MBIs IN GENERAL. Command and control and market-based incentives can achieve the same ambient quality, but market-based incentives are generally more cost-effective. CAC can possibly minimize the cost to society if the regulator tailors the abatement costs to each firm, so that no polluter is asked to reduce emissions if another can do so at lower costs. The policy is feasible if polluters are few and readily identified—for example, power plants emitting sulfur oxides in some cities. CAC by a strong regulatory agency may then be quite cost-effective. But generally, and especially in situations with many heterogenous polluters, a large informal sector, and weak public administration, command and control policies will not work so well. Furthermore, in practice, source-specific constraints allow marginal costs to vary among polluters, so that total costs of abatement are not minimized.

In contrast, market-based incentives generally require the regulator to estimate only aggregate (rather than individual) costs of abatement to minimize cost. A regulator would, for instance, issue enough tradable permits for the marginal benefits and costs of abatement to be equated overall; a polluter whose abatement costs are high would purchase permits, whereas one with cheaper abatement options would prefer to reduce emissions (Dales 1968 is an early proponent of this point). A pollution tax can also achieve cost-effective abatement. It allows each polluting source to decide whether to pay the tax or to undertake additional abatement, with the result that low-cost abatement is selected since each source will abate only if the marginal costs of abatement do not exceed the tax rate.

Empirical investigations have strongly supported the theoretical case for market-based incentives: cost saving is reported to be significant over the command and control alternative. Tietenberg (1988b) reviews nine studies in which market-based incentives are calibrated to reach the same ambience level as applied command and control methods. In seven of these studies, the ratio of MBI to CAC costs is 1:4 or lower; in two of them, the ratio is 1:14 or lower. Thomas's (1981) findings from São Paulo, with vastly differing abatement costs between firms and sectors, indicate that savings from market-based incentives would be high.

Market-based incentives are sometimes used in combination with command and control instruments to obtain some of the advantages of a more flexible approach without going to a full MBI system. In the United States, for example, some limited opportunities to "trade" the right to pollute within a command and control framework have been allowed in an attempt to gain some of the savings possible with market-based incentives (see Hahn 1989; Opschoor and Vos 1989). Expanded provisions for emission trading are among the amendments to the United States Clean Air Act (U.S. Government 1990). Some of the manifestations of emission trading have been netting, offsets, bubbles, banking, and lead trading.

- *Netting* allows for internal trades within a firm: a firm can avoid the stringent emission requirements for a new source if it reduces emissions from existing sources.
- *Offsets* are used in areas where the establishment of new polluting activities is banned because air quality standards are not met. Through the offset

provision, a new source may be created if it will reduce more emissions from another source than it will create itself. Germany and the United States have offset provisions.
- *Bubbles* place an imaginary "bubble" over a factory. This allows a firm to combine emissions from its various sources and comply with the general rather than the particular requirements.
- *Banking* allows a firm to earn credits if its emissions are under the legal limit; credits can be used later or sold to others.
- *Lead trading* between refineries in the United States was allowed in order to reduce the costs of a major program to phase out lead in gasoline (1982–87).

The savings from limited opportunities to trade within bounds like these are substantial if the trade allowed is between sources that would otherwise abate at vastly differing marginal costs. Hahn (1989) estimates that the savings related to netting, offsets, bubbles, and lead trading have been considerable.

PRICE-BASED VERSUS QUANTITY-BASED INCENTIVES. As long as there is no uncertainty about abatement costs, price-based incentives (such as taxes) and quantity-based incentives (such as tradable permits) have exactly the same effect. The same level of emissions and economic costs should result. A uniform emission tax will have the same incentive effects as emission permits, because the market will distribute them within the industry according to willingness to pay. Both minimize abatement costs overall, because high-cost abaters will either pay the tax or outbid low-cost abaters for permits.

But although taxes and permits that can be traded freely are conceptually equivalent, some analysts have argued that, for administrative reasons, tradable quotas may be preferable to tax or price instruments (Baumol and Oates 1988). First, adjustment of the tax rate to reach appropriate environmental goals may be costly, particularly in inflationary environments. Second, permits may be easy to implement, because they make it possible to introduce controls without increasing the costs for existing firms. But in some cases, tax-like instruments may be easier to administer than quotas. For example, an indirect pollution tax on fuel consumption may fit more easily into existing administrative processes than a quota (Anderson 1990). In most developing countries, input taxes to curtail emissions would be easier to implement than a completely new scheme such as permit trading.

Unless permits are auctioned, their distributive implications differ from those of taxes. Nonmarket distribution of permits, as well as other compensation schemes, must be designed with caution so as to avoid creating undesirable incentives.

SETTING PRICE-BASED INCENTIVES. Governments using a pollution tax to protect ambient quality should select a base and rate so that the external cost of the activity is internalized. Such an instrument is often called a Pigouvian tax.[2]

The appropriate base for the tax should be the damage caused or a close proxy for damage, such as the volume of emissions. An example might be a carbon tax, which has lately been proposed as a tool for efficient reduction of the emissions that cause global warming. Other examples are taxes applied on air pollution in France, on discharges into water in Germany, and on solid waste in Denmark (Whalley and Wigle 1991; Opschoor and Vos 1989).

The Pigouvian incentive can be either a tax on pollution or a subsidy for abatement. In the short term, the incentive effects can be the same. In the long term, when market entry and exit can be affected, a tax is normally preferable because it does not give firms incentives to enter a subsidized polluting industry.

What determines the rate of the tax? The general rule is to set taxes or public prices of commodities that produce externalities at a rate equivalent to marginal cost of production plus the incremental value of the externality (see Eskeland and Jimenez 1991 for a full discussion). There is no need to tax complements or to subsidize substitutes when the tax on the polluting good fully internalizes the externality. In practice, many polluting activities are subsidized, being priced at less than marginal cost (Schramm and Warford 1989; Repetto and Gillis 1988; Anderson 1990). In such cases, raising prices or taxes closer to marginal cost will already be an improvement over the present situation; emissions can be reduced with no cost at all.

Nonuniform Dispersion of Pollutants

The preceding discussion of policy instruments, for the purposes of comparison, has assumed uniform dispersal of pollutants. Greenhouse gases, such as carbon dioxide, *are* uniformly dispersed. But often pollutants are concentrated in some pattern around the source and downwind or downstream. Removing the assumption of uniform dispersal does not affect the general argument about the relative merits of command and control policies versus market-based incentives, but it does have implications for the details of policy design.

The damage (per unit of emission) caused by a polluting activity will vary, depending on location, on the dispersion characteristics of emissions (determined, for air pollution, by such variables as stack height or speed and temperature of flow), and on the site being polluted. For many major air pollutants, reducing emissions has few benefits over vast rural areas, so that applying uniform emission charges (or one-for-one tradable emission permits) in zones comprising both urban and rural areas would not be cost-effective. The rural/urban dimension illustrates differences in marginal damages per unit of emissions. The principle, and the need for differentiated instruments, is valid for any pattern of nonuniform damages (or, equivalently, benefits). Area A may be vulnerable, but less important to protect than area B if higher present pollution loads in B make the marginal damage there higher. Similarly, for water pollutants such as those characterized by biological oxygen demand, marginal damage from discharges may be high where discharges are high but lower both upstream and downstream. Uniform emission charges might require unnecessary abatement from many sources whose emissions do not pollute the "hot spots." In these cases, the most cost-effective program would require abatement for each source according to whether its emissions pollute vulnerable locations or not. For example, emission charges could vary by location to reflect the ratio of damages to emissions.

In essence, differences in damages per unit of emissions mean that unlimited trading of emission permits is not a good idea. If zoning is in effect, permits need to be distributed carefully among zones, since sources are barred from solving problems of misallocation through trades.

If the polluters in a region display very different ratios of damages to emissions, differentiating instruments accordingly can yield significant cost savings. By the same token, the costs of applying uniform emission charges or permits without zoning will also be high. Atkinson and Tietenberg (1982) calculate that a market-based scheme for particulate emissions in St. Louis would save 83 percent of the costs of a command and control scheme if charges were fully differentiated. The savings would be lower if geographical differentiation of emission charges were limited, and would be only 50 percent if charges were uniform throughout. Seskin, Anderson, and Reid (1983), modeling control strategies for nitrogen oxides in Chicago, find that savings of 93 percent relative to command and control fall to 50 percent if instruments have to be uniform within industries, whereas a scheme with completely uniform instruments would cost twice as much as the command and control strategy. The regulators, not surprisingly, have had an eye on the geographical dimension when designing the command and control scheme, and thus it did better than a market-based scheme that ignored geography.

Efficient Pollution Control Policy in Developing Countries

How are the standard results just discussed affected when we change the standard assumptions? Let us assume a public revenue constraint, inability to monitor emissions and damages, uncertainty, and a market structure that is not competitive—constraints that confront policymakers in many developing countries.

Pigouvian Taxes under a Public Sector Revenue Constraint

Public budgets are often tight in developing countries. Raising additional revenue through existing tax structures can injure resource allocation, as firms and households adapt to a distorted price regime. And such distortions can be immense: estimates from the United States assess costs at 17 to 56 cents for every additional dollar of tax collected (Ballard, Shoven, and Whalley 1985). In developing countries, where the tax base is often narrow and rates high, distortionary costs are likely to be higher (World Bank 1991).

One attraction of pollution taxes is that they can raise revenue while improving efficiency, by persuading firms and households to reduce negative externalities. Taxing commodities with negative externalities will thus reduce not only the efficiency losses arising from the externality itself (say, damage from pollution) but also the efficiency losses related to generating revenue, since the proceeds may allow other rates to be reduced.

How much can be raised by such efficient taxes? Sandmo (1975) shows theoretically that pollution taxes belong in an optimal tax structure, adding to the rates on polluting goods. Some empirical studies indicate that revenues from efficient pollution control policies will be of the same order of magnitude as total control costs. In a simulation of particulate control in St. Louis, Atkinson and Tietenberg (1982) found that proceeds from permit charges would be in the same range as abatement costs. The study of control strategies for nitrous oxides in Chicago (Seskin, Anderson, and Reid 1983) also found charges in the same range as control costs.

So far, charges have not made an impressive contribution to general revenue in OECD countries. At less than a third of 1 percent of gross national product (GNP) in the Netherlands and at 0.04 percent or less of GNP in the other countries surveyed, the revenues were found to be of no importance for the general budget (Opschoor and Vos 1989). The OECD study further showed that charges were rarely effective in changing behavior because rates were too low and the base was usually insufficiently responsive to individual behavior. But proceeds from pollution charges were an important mechanism for funding selective environmental expenditures in countries where they were earmarked for that purpose. Indirect taxes, such as fuel taxes, could be important in generating revenue: for countries such as Pakistan, the Republic of Korea, and Turkey, a 20 percent increase in the tax on fossil fuels could raise an additional 3–5 percent of revenue. Gil Diaz (1987) found that energy subsidies in Mexico from 1977 to 1984 amounted to $100 billion—equal to the total amount of foreign public debt. Clearly, the budgetary implications of energy pricing can be immense.

Pollution charges may yield more or less than what is needed for environmental expenditures, so the benefits of earmarking should be examined in the broader context of public expenditure analysis (see McCleary 1991 on the pros and cons of earmarking).

Monitoring Damages or Emissions: A Role for Indirect Instruments

The theory reviewed earlier implies that the efficient economic policy (whether market-based or command and control) is to address the external effect directly—for instance, by taxing a polluter or regulating emissions according to the environmental damage caused. In practice, monitoring damages or even emissions at the source may be costly, particularly in developing countries, for technological and institutional reasons. The emissions of many pollutants can only be imperfectly monitored, and the fact that the results of monitoring may cost the polluter money does not make the task easier. In the United States the Environmental Protection Agency (EPA) has 14,000 federal employees, and even so, it monitors very few sources continuously. Russell (1990) notes that the EPA largely trusts corporations in matters of compliance and self-reporting, even though experience with motor vehicles has shown that active tampering (not only inadequate operation and maintenance) is prevalent (see also Hamrin 1991). The monitoring problem is likely to be worse for regulatory agencies in developing countries, since the agencies are often inadequately funded and have less access to technology and trained labor. In Mexico only three plants are scheduled to install equipment for continuous monitoring of emissions; the rest of the 300 most-polluting firms report their own emissions.

To be credible, regulatory agencies must be able to design and administer new schemes; behavior will change only if a threat to penalize noncompliance is seen to have teeth. Even in industrial countries, sophisticated schemes, such as permit trading, have run afoul of implementation issues (Hahn 1989). And even when monitoring is technically feasible, institutions may be too weak to enforce the taxes or regulations based on the monitoring.

When environmental damage or emissions cannot be tackled directly because monitoring and enforcement costs are too high, the regulator will use indirect instruments aimed at the outputs and inputs of the polluting industry or substitutes and complements to its outputs. Indirect pollution taxes applied to fuels such as coal and gasoline—presumptive Pigouvian taxes—are an example. How would the use of such instruments affect the policy choices discussed earlier? With indirect instruments, the "tradability" results apply, in that actions that reduce (increase) emissions by an equal amount should receive an equal subsidy (tax). Indirect instruments, however, typically specify physical actions (such as installation of catalytic converters) rather than emission reductions, and they often yield more emission reductions at one place than another. Investments that reduce emission coeffcients for vehicles, for instance, yield highest benefits for the vehicles that are used most intensively. For this reason, indirect instruments will often need to be applied with stronger inducements to specific polluters and, consequently, will have aspects of command and control. An example in which this principle is applied: In Mexico City, high-use vehicles such as taxis and minibuses are required to be cleaner than vehicles in general. Presumptive emission taxes on fuel will thus be effective if emission coefficients for one fuel are the same across users, but they should otherwise be differentiated, if possible. The cement industry, for instance, which does not discharge the sulfur of its fuels, should ideally be refunded presumptive sulfur taxes on fuels.

In assessing the desirability of indirect instruments, the reduced cost of the externality must be compared with the distortions the instruments themselves create through their effect on other choices. A fuel tax, for instance, is efficient if the relationship between consumption and emissions is fixed, if nonpolluting fuel use will be unaffected, and if fuel consumption can be monitored relatively easily. A fuel tax is relatively inefficient, however, for fuel used in polluting as well as nonpolluting activities. Furthermore, other effective abatement measures (such as catalytic converters and scrubbers) are not triggered by fuel economy and thus require instruments other than fuel taxes. Deposit refund systems, similarly, can be attractive when unsafe disposal, rather than use, causes damages (Bohm 1981).

Indirect instruments are blunter tools for tackling pollution in that they may also have undesirable effects on behavior. How can such side effects be minimized?

OUTPUTS AND INPUTS AS A BASE. If a polluter's emissions are fully determined by the consumption of one good, then taxing the good according to marginal external costs is equivalent to an emission tax. Carbon taxes on fuels are an example, because the external effects are independent of both source location and combustion process. But if a polluting good cannot be fully taxed, a related good should be taxed if it is a complement to the polluting good, and subsidized if it is a substitute good. For example, suppose that private vehicle use in urban areas is polluting but cannot be taxed sufficiently (or only at a prohibitive cost). A clean substitute such as a subway should be subsidized, but a clean complement such as central parking facilities should be taxed. This holds unambiguously as long as demand for subway service is unrelated to demand for parking space.

Wijkander (1985) shows that taxation of complements and subsidization of substitutes are efficient under fairly general assumptions, but counterintuitive results can take place depending on own-price and cross-price elasticities of demand. These occur when the indirect instruments bring unintended distortions. In our motor vehicle example, if public transport and central parking facilities are sufficiently strong substitutes for each other, subsidizing subways and taxing parking spaces may lead to overutilization of subways. If this problem arises, parking space should not be taxed so much and may even have to be subsidized.

Sandmo (1976) presents another situation in which indirect instruments are useful. A commodity is used by consumers for two purposes, only one of which has negative external effects. Gasoline use, for example, can be said to be "innocent" when used for countryside driving, but it has negative external effects in terms of pollution and congestion when used in cities. A commodity tax to address the externality is then itself distortionary in relation to the innocent use, and the question is whether an additional instrument on a related good can reduce the costs of that distortion. Sandmo concludes that a related good should be taxed if it is a complement to the polluting activity and a substitute for the "innocent" activity, and subsidized if it is a complement to the "innocent" activity while a substitute for the polluting activity. Intuitively, supplementing gasoline taxes with taxes on central parking and central road use, and subsidizing parking at peripheral metrorail and bus stations, would fit in this picture. If the related good is a complement to *both* uses, it should be taxed if it is more complementary to the polluting use, but subsidized if it is more complementary to the "innocent" use. Likewise for a substitute good: it should be subsidized if it is more substitutable to the polluting use, but taxed if it is more substitutable for the "innocent" use. For instance, if bus services are substitutes for polluting cars, but also for "innocent" bicycles, then one would subsidize buses only to the extent that the former effect is stronger. (See Sandmo 1975 and Balcer 1980 for further illustration of this point.)

There are several possible bases for pollution taxes:

- *Taxing the damage created* makes it possible to differentiate between polluters according to the amount of damage caused per unit of emission. Each source balances marginal abatement costs equally against individual differentiated marginal benefits. No such taxes have yet been applied. Other damage-related instruments are used, however. Liability rules hold polluters accountable for accidents, such as oil spillage (a market-based incentive). Offsets, bubbles (market-based), and zoning policies (market-based and command and control) give some consideration to the location of the source and thereby to the amount of damage it creates. Ambience permit systems are markets in damage quotas and have been simulated but not tried in practice.
- *Taxing emissions* minimizes the costs of abatement by equalizing marginal abatement costs across sources but does not differentiate between sources according to damages. Emission charges thus fail to provide incentives to relocate within a region. Examples include France's tax on emissions to air, water charges in Germany, waste charges in Denmark, manure taxes in the Netherlands, and carbon taxes in Norway.
- *Taxing inputs and outputs of polluting activities* mimics an emission or damage tax (imperfectly) but fails to give incentives to minimize emissions or damages for a given level of inputs or outputs. As an example, lead in gasoline is taxed in Norway and Germany. Many countries also tax fossil fuels in general.
- *Taxing (or subsidizing) fixed inputs of polluting activities* can provide some abatement incentive, but fails to influence how carefully and frequently the equipment is maintained and used. Tax differentiation is applied according to emission characteristics of cars in Germany, the Netherlands, Norway, and Sweden. Many countries tax noise characteristics of aircraft and subsidize or mandate the installation of "clean" equipment or processes.
- *Taxing complements and subsidizing substitutes* are alternatives if the polluting activity is untaxable; they can also be valuable supplementary instruments. Apart from complementary inputs (vehicles), complements are

not otherwise known to have been taxed. As a substitute for private transport, urban mass transport is subsidized almost everywhere.

- *Taxing unreturned items.* Depending on cost relationships, many materials will be recycled without government intervention, particularly if labor is cheap. When additional incentives to recycling are desirable because of external costs, a deposit refund system may be efficient. Such systems have been proposed for batteries and are in place for car hulks and beverage containers in Scandinavia.

FIXED INPUTS. If one cannot monitor emissions or variable inputs and outputs, one can still achieve something by targeting fixed inputs, such as equipment and installations. When it is difficult to observe what people do and earn, governments have often resorted to presumptive taxation to raise revenue, basing the taxes on observable proxies for income such as land ownership or house size. To correct for externalities, the analogous approach would be to tax pollution-generating equipment as if it were used (when use is unobservable) and to tax cleaner equipment at a lower rate. Unlike presumptive taxes used for revenue collection, presumptive taxes on pollution make sense only if they affect behavior.

Technical standards can thus be regarded as indirect instruments under monitoring costs. In the United States the costs of monitoring emissions continuously are prohibitive not only for mobile sources, but often for stationary sources as well (Hamrin 1991). In the United States, Mexico, and many other countries, emissions from mobile sources are controlled through testing of new sources (and in some places through annual testing), even though the results are imperfectly correlated with actual emissions.

Technical standards have been heavily criticized by economists because they tend to be applied in a mandatory, uniform, and thus excessively costly way—and generally in the form of command and control policies, instead of through selective taxes or subsidies on equipment that are differentiated according to presumed emissions. Often, regulations are applied only to new sources, failing to exploit abatement opportunities among other sources. Another problem with this "new-source bias" is that it may increase the market power of incumbents.

Many developing countries now follow the United States's example in lowering vehicle emissions mainly by setting strict tailpipe standards for new vehicles. Thus the major instrument for control is a source-specific constraint applied to equipment, as opposed to emission taxes or taxes on variable inputs such as fuels and road use. The strategy certainly reduces emissions per kilometer traveled. It would be more productive, however, when combined with fuel taxes or other instruments that encourage people to buy smaller vehicles or use their vehicles less.

The effects of indirect instruments are often subtle, because they are frequently a stopgap device, instituted to compensate for the lack of first best instruments. Take, for example, the interaction between standards for new vehicles and a proposed presumptive Pigouvian tax on fuels in Mexico City. As new cars are purchased, the vehicle fleet will become cleaner *and* larger. Whether the Pigouvian tax should decline over time as the fleet becomes cleaner on average depends on whether the air pollution situation overall deteriorates or not.

Charges and Permits under Uncertainty

Even under perfect monitoring, the effects of environmental policies may be uncertain. The benefits from abatement may be subject to events that are inherently difficult to predict. For example, the effects of air pollution can depend on the health of the affected population—about which there is little information in developing countries. Furthermore, the costs of abatement depend on how easily polluters adjust, which a regulator cannot know with certainty.

The standard recommendations about the choice of instruments are affected by uncertainty in three ways: (a) the equivalence of price-based versus quantity-based instruments may no longer hold; (b) in an uncertain environment, flexible instruments are better; and (c) liability rules may be an attractive option.

PRICE-BASED VERSUS QUANTITY-BASED INSTRUMENTS UNDER UNCERTAINTY. When the marginal costs of pollution abatement are known to the regulatory agency, uncertainty about the benefits does not favor one type of instrument over the other. Firms' abatement response depends only on costs and on the policy instrument, which are both known to the firm. So, even if the benefits deviate from expected levels, the abatement level and the efficiency losses will be exactly the same whether the price or the quantity instrument is used.

When abatement costs are uncertain to the agency, producers are assumed to have information that the agency does not have (Weitzman 1974). The quantity instrument, which can guarantee an emission level, is better if unexpected emission loads are costly. This would occur if marginal damages from unexpectedly high emissions are steep (as with leaks from nuclear facilities). Correspondingly, the price instrument, which guarantees that marginal abatement costs do not exceed the tax rate, is better when marginal damages are relatively flat.

In an empirical study, Kolstad (1986) evaluated policies to control sulfur emissions from power plants, where abatement costs were uncertain because of uncertainty about future electricity demand. He found that if marginal benefits were constant, a price instrument would be slightly preferable, but that a mild slope would be enough to make permits the more desirable option. Lyon (1989) argues that tradable permits are particularly attractive to developing countries because they provide certainty about ambient quality in a dynamic context, and they also allow implicit property rights to be changed gradually.

However, if marginal benefits are seen as fairly flat, then price instruments do have the attraction of placing a definite upper bound on control costs.

A combination of instruments may be the solution. Roberts and Spence (1976) suggest a permit to be accompanied by a (high) fee for further emissions and by a promise to repurchase unused parts of the permit (as a subsidy for additional abatement) at a (low) price. As they explain, "The subsidy provides a residual incentive for firms to clean up even more when costs are low. The finite penalty provides an escape valve if costs are very high" (page 203).

FLEXIBILITY OF INSTRUMENTS. What if the planner can adjust policy instruments when information is revealed? The results just mentioned may change if some instruments are more easily adjusted than others. Bawa (1988) suggests a mixed policy under the assumption that a regulatory policy (command and control) can be put into effect faster and more flexibly than a charge (or a tradable permit).

Suppose, for example, that stochastic changes (such as weather) make the ambient quality resulting from a steady flow of emissions worse in some periods than others, but the periods are too short for the effluent charge to be adjusted. An emission tax can then be complemented by a command and control instrument—for instance, factories are closed down under a "smog alert" (see Plourde and Yeung 1989). In practice, pollution control authorities are often authorized to shut down polluting activities selectively on short notice. In several cities in Brazil and also in Mexico City, industries are shut down during crisis periods (Sebastian forthcoming). Both Mexico City and Santiago close central areas to traffic when air pollution reaches threshold levels.

LIABILITY RULES. If monitoring of actions to avoid causing damage is expensive but the source of discharges or spills can be identified, a liability rule might usefully substitute for a regulation (Bohm and Russell 1985). This view of liability is similar to the Coasean proposition about negotiation—that negotiation between polluters and victims can take the place of government intervention—but it explicitly requires support from a legal system. Liability rules will usually distribute property rights, for instance, by postulating that everybody has the right not to be harmed by others. Liability rules can be seen as a complement to other regulations (Posner 1986; Farrel 1987) and will then undoubtedly allow for more flexible case-by-case damage assessment. Incidents such as the Bhopal catastrophe and the Prince William's Sound oil spillage (with sizable damage awards and losses of reputation for the responsible firms) warn firms of their potential liability and thus induce them to take more precautions.

But there are many potential problems that might limit the usefulness of liability rules: low likelihood that offenders will be detected, high costs to victims for representation and litigation, the unpredictability of an underdeveloped judicial process, and the potential insolvency of the liable party. Ringleb and Wiggins (1990) find that in the United States, where liability is generally unlimited, industries prone to litigation are increasingly being dominated by small, independent firms. Shell, for instance, pulled out of oil transport in U.S. waters in 1990. This pattern could indicate that less wealth is backing the potential liabilities, in which case the incentives given may be less powerful, since owners have little to lose. Bohm and Russell (1985) note that the liability instrument may encourage people not to protect themselves against pollution, since the price paid by the polluter is actually passed on to the victims. Kolstad, Ulen, and Johnson (1990) add that uncertainty about liability assessment gives a rationale for supplementing ex-post liability with ex-ante regulatory standards.

Noncompetitive Market Structure

The rules of policy intervention generally assume that markets are competitive. But often that assumption is untenable. In industrial countries, utilities are prime examples of monopolies; they are often subject to controls on both pricing and emissions. In developing countries, many markets may be small; entry barriers, tariffs, and transportation costs high; and access to credit, technology, and law enforcement limited. Utilities and some industries are often public and loss-making, and profit maximization—or even cost minimization—may not be a primary objective.

How do the recommendations for policy intervention change when the polluting firm is also a monopoly (such as a utility) whose market power permits it to supply less than optimal output? In such a case there are two sources of market failure—pollution externalities and market power. Indeed, it is theoretically possible (since output is lower from a monopoly than from a competitive firm) that the exercise of monopoly power may partially address the pollution externality (Buchanan 1969). There would be efficiency gains with two instruments to address each source of market failure. But, if a tax to address the externality directly were infeasible, an output tax would address both problems and would be the sum of a Pigouvian tax and a subsidy to output (Baumol and Oates 1988).

Market power introduces a more serious problem if abatement is to be regulated within a market for pollution permits. If the permit market does not result in competitive pricing, abatement will not be efficiently distributed, even if the number of permits available is optimal. That permit markets will often be fragmented and interdependent may be an additional argument for using price instruments. If polluters behave strategically to manipulate the charge, however, problems similar to those in permit markets will emerge (see Jack 1990).

Different policies may affect firms' entry into and exit from markets, and thereby the extent of their market power (Dewees 1983; Kohn 1988; Spulber 1985). This intuitive conclusion runs counter to the finding in short-term static models that nonmarginal rewards are neutral. The most important consideration is probably that quotas and standards, if they raise the costs of entry, could provide for collusion among existing firms. Assuming competitive behavior, Spulber (1985) shows that an optimal effluent charge (or number of tradable permits) will yield the efficient number of firms and efficient output even if there are economies or diseconomies of scale in production and abatement.

There are many claims that industries in industrial countries (paper and pulp, for example, and copper smelting) have become more concentrated as a result of environmental control policies. This may, however, be a response to excessive concentration on mandated equipment, or a reflection of the fact that abatement requirements usually favor incumbents, thereby discouraging new entrants. (As noted earlier, abatement activities that rely on equipment and fixed installations may justifiably be preferred to other, equally cheap abatement options if they are less costly to monitor.) There are also examples, such as fossil-fueled power generation and steel production in the United States, where pollution control policies have eroded some economies of scale, thus giving a boost to small plants (Gollop and Roberts 1983).

In developing countries, small firms in the informal sector are often major polluters. Restructuring and concentration in an industry could lower the costs of monitoring and enforcement, but using flexible instruments such as taxes and regulation of inputs may also save on those costs. This may be a way to curb emissions from small firms without forcing them underground or out of business.

Distributive Effects: Welfare and Political Economy

The distributive effects of alternative pollution control policies are important for two reasons. First, an increase in income may be valued more highly for the poor than for others. Second, the government should know who gains and who loses so that it can judge whether a particular reform will have sufficient political support.[3]

Environmental Policies and the Poor

The distribution of the benefits of pollution control is an empirical issue, and the evidence on the differential health effects of reducing pollution is mixed. Several authors have noted that the poor are likely to benefit more (see Anderson 1990; Asch and Seneca 1978), because they tend to live in unhealthy, unsanitary conditions in polluted urban areas and cannot afford to protect themselves or move. Some U.S. studies (see Christiansen and Tietenberg 1985 for a review) support this view—they show that air pollution is worse in cities with many poor residents and, within cities, in the areas where the poor live. Theoretical arguments and some empirical evidence, however, indicate that wealthier people may be more willing to pay for environmental improvement than the poor. This could make the wealthy the principal beneficiaries of control policies (Johansson 1987; Christiansen and Tietenberg 1985).

Most of the researchers comparing the incidence of costs assume the distribution of benefits to be uniform. An exception is Harrison (1975), who notes that the policies to control air pollution from motor vehicles in the United States have affected the rural poor badly—their car ownership rates (and thus control costs) are necessarily high because they have no public transportation alternatives, and the environmental benefits in their areas are modest. In the 1990 Clean Air Act Amendments (U.S. Congress 1990), emission standards for vehicles were made stricter only in the most polluting cities, and this could somewhat reduce the costs to households that derive only minor benefits. Such differentiation makes pollution control harder to administer but perhaps more efficient, if damages per unit of emissions are lower in less polluted areas. As for water pollution in developing countries, it is clear that the wealthy can protect themselves from exposure. Private wells, piped water, and bottled water are available to households that can afford them, leaving the poorer families most vulnerable to surface water conditions.

The incidence of the costs of alternative pollution policies depends on the ability of polluters to pass on the costs to customers, to other producers (if intermediate goods are produced), and to workers. Thus, the elasticities of demand and supply in production and consumption must be analyzed along with the amount that poor households spend on the polluting goods. A higher gasoline tax, for example, may have very little effect on slum dwellers who own no cars and do not use public transport. A diesel price hike may affect commuters and rural communities; vulnerability will depend on the availability of substitutes. Regulatory intervention can also have distributive effects because it affects the cost of doing business, which can be shifted forward to prices or backward to labor and capital. The poor may be especially vulnerable to selective price increases and at greater risk of unemployment if an industry becomes uncompetitive (Yu and Ingene 1982; Yohe 1979).

In industries for which environmental regulations are very costly, changes in costs and practices may affect incidence. For example, if labor is a substitute for polluting inputs (labor and energy are often substitutable), abatement policies can lead to increased labor-intensity in production and can thus increase employment or remuneration of labor. Another situation arises when abatement does not change input combination but simply raises costs in the industry. Assuming flexible prices, Forster (1983) uses a simple theoretical general equilibrium framework to show that the factor most intensively used in the polluting sector will lose remuneration, while the other factors will earn more. Alternative assumptions, such as the introduction of price/wage rigidities (and possible unemployment) or immobile factors would affect the results.

Most empirical studies incorporating the incidence of costs do not explicitly compare alternative instruments. Pearson and Smith (1990) find that carbon taxes sufficient to reduce carbon emissions in the United Kingdom by 20 percent would raise £8 billion in the short run and would be highly regressive, reducing the real income of the very poor by up to 2.7 percent compared with only 0.4 percent for the very rich.[4] They do find, naturally, that if all the proceeds from the carbon tax were redistributed to the poor, the scheme could end up being progressive.

Because the poor most likely spend more of their income, price increases generally tend to have a regressive effect (Gianessi, Peskin, and Wolff 1979; Dorfman 1975), although this may be seen as a transitory phenomenon. Over and above this, Yan and others (1975) found no pattern of regressiveness or progressiveness arising from the specific prices that increased as a result of environmental policies. Water pollution treatment, which is typically partially financed through charges and taxes, appears to have been progressive in some cases and regressive in others.

Lessons about presumptive Pigouvian taxes on marketed goods and services can be derived from empirical studies in developing countries. An internal World Bank study on Indonesia found that the average household spends 4.2 to 4.5 percent of its income on fuels and 0.2 to 0.3 on transport. Among manufacturing industries, no industry had an elasticity to costs of fuel prices higher than 9 percent (most are in the range of 1–3 percent), and labor was assumed to be a substitute for energy. Another internal World Bank study, on Mexico, found that wealthy households spend a higher share of their budgets on transport and communication, suggesting a good tax base for distributive purposes.

Political Economy and Implementation

If some instruments are so much better than others (for instance, market-based incentives rather than command and control, direct rather than indirect), why are they not applied more in practice? Many researchers have shown that policy outcomes are influenced not so much by net gains to society as by who gains and who bears the burden of different strategies. (See Hahn 1989 for a brief review and interpretation; see also Baumol and Oates 1979, 1988; Dewees 1983; Buchanan and Tullock 1975.) If a group that prefers one instrument over another can influence policy decisions, it is likely that a policy will be chosen that does not minimize costs. For example, Buchanan and Tullock (1975, pp. 141–42) compare regulation to an effluent tax, and note:

> Regulation is less desirable on efficiency grounds...but this instrument will be preferred by those whose behavior is subjected to either one or the other of the two policy instruments.... [In] their own

> private interests, owners of firms in the industry along with employees will oppose the (effluent) tax. By contrast, under regulation firms may well secure pecuniary gains from the imposition of direct controls that reduce total industry output.... This political choice setting is...the familiar one in which a small, concentrated, identifiable and intensely interested group may exert more influence on political choice making than the much larger majority.

Thus, a tax on emissions is unpopular among influential polluting industries that, for any given level of abatement effort, strongly prefer not to pay for the remaining emissions. The regulatory agency, for its part, is likely to settle for any solution that is consistent with its ambient quality goals. Those who pay the additional costs of inefficient intervention are citizens at large, who are often badly organized compared to the industry in question. In addition to the inefficiency problems already mentioned, real-world command and control policies tend to be selective and thus very susceptible to rent-seeking behavior.

Political economy—the study of how distributive effects affect decisions—can also be important in setting priorities among environmental problems. Dixon (1991) argues that the wealthy can privately avoid the consequences of water pollution to a greater extent than they can avoid the consequences of air pollution, and that as a result, water pollution control will lag in the policy process.

Implications for Policy Reform

Which policy instruments are more efficient, practical, and equitable under the constraints that developing country governments confront? What research must be done to provide better answers to the questions we have raised?

The stringent budgetary restrictions in developing countries probably strengthen considerably the case for price-based versus quantity-based interventions, particularly if the instruments are related only indirectly to damages or emissions.

Even though quantity-based interventions (such as tradable permits) can incorporate aspects of market-based incentives, they will in most cases require new administrative systems. For indirect instruments, many governments already have ways of charging for or taxing relevant commodities, and the administrative capacity to manipulate domestic relative prices is generally well established. What price-based interventions and permits have in common is that they can generate revenue. But the potential revenues from pollution control instruments are likely to be small in relation to the overall needs of the treasury—except in the case of fuel taxes, which can generate vast revenues.

In an uncertain world, price-based instruments provide greater certainty about abatement costs. Such instruments are superior when there are concerns that underestimating costs would yield controls that are "too strict" and environmental quality that is "too high"—concerns that arguably trouble policymakers in many developing countries.

The costs of monitoring individual emissions and enforcing their abatement can be high, particularly in developing countries, for technological and institutional reasons. Indirect taxes or subsidies for marketed inputs and outputs are desirable alternatives because they depend less on vulnerable and costly monitoring and enforcement functions. But these instruments also imply additional costs because they can only imperfectly mimic taxes on monitored emissions and damages. The choice of which commodities to tax and at what rates should be sensitive to demand relationships, which play a role in emission reduction and in the probable incidence. These empirical issues should be the subject of future research.

The considerations raised in this article do not mean that instruments such as tradable permits should not be tried out, but that less sophisticated instruments should be considered wherever they can potentially do much of the job in an easy-to-implement, low-cost way. Then, monitoring and enforcement capacity can be developed and priorities set for remaining problem sectors or pollutants. Schemes that encourage self-compliance, such as deposit refund systems, should also be considered.

Notes

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1. On the long-term efficiency of the negotiated solution with well-defined property rights, see Frech (1973) and Tybout (1972, 1973). Efficiency can be the result if firms that leave or enter a market can charge or be charged for doing so. For a discussion of incentive-compatible demand revelation, see Groves and Ledyard (1977) and Green and Laffont (1979). Farrel (1987) uses a simple approach to show that an intervening bureaucrat may be more efficient than negotiations, even when the bureaucrat is limited by poor information and there are only two agents.

2. Since A. C. Pigou's (1920) seminal contribution, the expression "Pigouvian taxes" has been used for taxes intended to discourage activities with negative externalities. The "polluter pays" principle, as defined by OECD guidelines (OECD 1975; Opschoor and Vos 1989) is not a "true" Pigouvian instrument, because it usually requires payment for abatement but not for damages from emissions.

3. The perspective of this article is policy analysis under a well-defined welfare objective. In this context, insights from public choice models are relevant mostly for problems of policy adoption and implementation. See Buchanan and Tullock (1975) and Hahn (1989) for applications to environmental policies.

4. This calculation is a rough approximation using Roy's identity and a money measure of utility.

References

The word "processed" describes informally reproduced works that may not be commonly available through libraries.

Anderson, Dennis. 1990. "Environmental Policy and the Public Revenue in Developing Countries." Environment Department Working Paper 36. World Bank, Washington, D.C. Processed.

Atkinson, Scott E., and T. H. Tietenberg. 1982. "The Empirical Properties of Two Classes of Designs for Transferable Discharge Permit Markets." *Journal of Environmental Economics and Management* 9: 101–21.

Asch, Peter, and Joseph J. Seneca. 1978. "Some Evidence on the Distribution of Air Quality." *Land Economics* 54: 278–97.

Balcer, Yves. 1980. "Taxation of Externalities, Direct Versus Indirect." *Journal of Public Economics* 13: 121–29.

Ballard, C. L., J. B. Shoven, and John Whalley. 1985. "General Equilibrium Computations of the Marginal Welfare Costs of Taxes in the United States." *American Economic Review* 75: 128–38.

Bawa, V. S. 1988. "On Optimal Pollution Costs of Policies." In Baumol and Oates 1988.

Baumol, William J., and Wallace E. Oates. 1979. *Economics, Environmental Policy and the Quality of Life.* Englewood Cliffs, N.J.: Prentice Hall.

———. 1988. *The Theory of Environmental Policy.* Cambridge and New York: Cambridge University Press.

Bernstein, Janis D. 1991. "Alternative Approaches to Pollution Control and Waste Management: Regulatory and Economic Instruments." Urban Management Program Discussion Paper 3. World Bank, Washington, D.C. Processed.

Binswanger, Hans P. 1989. "Brazilian Policies That Encourage Deforestation in the Amazon." Environment Department Working Paper 16. World Bank, Washington, D.C. Processed.

Bohm, Peter. 1981. "Deposit-Refund Systems: Theory and Applications to Environmental, Conservation, and Consumer Policy." Published for Resources for the Future. Baltimore and London: The Johns Hopkins University Press.

Bohm, Peter, and C. S. Russell. 1985. "Comparative Analysis of Alternative Policy Instruments." In Allen V. Kneese and James L. Sweeney, eds., *Handbook of Natural Resource and Energy Economics.* Vol. I. Amsterdam: North Holland.

Buchanan, James M. 1969. "External Diseconomies, Corrective Taxes and Market Structure." *American Economic Review* 59, no. 7 (March): 174–77.

Buchanan, James M., and Gordon Tullock. 1975. "Polluters' Profit and Political Response: Direct Controls Versus Taxes." *American Economic Review* 59, no. 7 (March): 139–47.

Christiansen, G. B., and T. H. Tietenberg. 1985. "Distributional and Macroeconomic Aspects of Environmental Policy." In Allen V. Kneese and James L. Sweeney, eds., *Handbook of Natural Resource and Energy Economics.* Vol I. Amsterdam: North Holland.

Coase, Ronald. 1960. "The Problems of Social Costs." *Journal of Law and Economics* 3: 1–44.

Dales, J. H. 1968. *Pollution, Property and Prices.* Toronto: University of Toronto Press.

Dewees, Donald N. 1983. "Instrument Choice in Environmental Policy." *Economic Inquiry* 21 (January): 53–71.

Dixon, J. A. 1991. "The Social Costs of Urban Pollution in Latin America: Incidence and Implications." World Bank, Latin America Technical Department, Washington, D.C. Processed.

Dixon, John, and G. Hodgson. 1988. "Logging Versus Fisheries and Tourism in Palawan: An Environmental and Economic Analysis." EAPI Occasional Paper 7. East/West Center, Honolulu, Hawaii. Processed.

Dorfman, N. S. 1975. "Who Will Pay for Pollution Control? The Distribution by Income of the Burden of the National Environmental Protection Program, 1972–1980." *National Tax Journal* 28: 101–15.

Eskeland, Gunnar, and Emmanuel Jimenez. 1991. "Choosing Policy Instruments for Pollution Control: A Review." Policy, Planning, and Research Working Paper 624. World Bank, Country Economics Department, Washington, D.C. Processed.

Farrel, Joseph. 1987. "Information and the Coase Theorem." *Journal of Economic Perspectives* 1, no. 2: 113–29.

Forster, Bruce A. 1983. "The Backward Incidence of Pollution Control: A Dual Approach." *Journal of Environmental Economics and Management* 11: 14–17.

Frech, H. E., III. 1973. "Pricing of Pollution: The Coase Theorem in the Long Run." *The Bell Journal of Economics and Management Science* 4, no. 1: 316–19.

Gianessi, L. P., Henry M. Peskin, and Edward Wolff. 1979. "The Distributional Effects of Uniform Air Pollution Policy in the United States." *Quarterly Journal* 91: 654–74.

Gil Diaz, Francisco. 1987. "Debt Accumulation and Distorted Growth through Subsidized Public Sector Prices." Banco de Mexico. Processed.

Gollop, Frank M., and Mark J. Roberts. 1983. "Environmental Regulations and Productivity Growth: The Case of Fossil-Fueled Electric Power Generation." *Journal of Political Economy* 91, no. 4: 654–74.

Green, Jerry, and J. J. Laffont. 1979. *Individual Incentives in Public Decision Making.* Amsterdam: North Holland.

Groves, Theodore, and John O. Ledyard. 1977. "Optimal Allocation of Public Goods: a Solution to the 'Free Rider' Problem." *Econometrica* 45: 783–809.

Hahn, Robert W. 1989. "Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders." *Journal of Economic Perspectives* 3, no. 2 (Spring): 95–114.

Hamrin, Robert. 1991. "Monitoring and Enforcement of Pollution Control—Lessons from the U.S. Experience." World Bank, Country Economics Department, Washington, D.C. Processed.

Harrison, David, Jr. 1975. *Who Pays for Clean Air: The Cost and Benefit Distribution of Automobile Emission Standards.* Cambridge, Mass.: Ballinger.

Hertzman, Clyde. 1990. "Poland: Health and Environment in the Context of Socioeconomic Decline." Internal Document 13. University of British Columbia, Vancouver. Processed.

Jack, W. G. 1990. "Power Sharing and Pollution Control: Coordinating Policies among Levels of Government." Policy, Planning, and Research Working Paper 887. World Bank, Country Economics Department, Washington, D.C. Processed.

Johansson, Per-Olov. 1987. *The Economic Theory and Measurement of Environmental Benefits.* Cambridge: Cambridge University Press.

Kohn, Robert E. 1988. "Efficient Scale of the Pollution-Abating Firm." *Land Economics* 64, no. 1 (February): 53–61.

Kolstad, Charles. 1986. "Empirical Properties of Economic Incentives and Command-and-Control Regulations for Air Pollution Control." *Land Economics* 62, no. 3 (August): 250–68.

Kolstad, C. D., T. S. Ulen, and G. V. Johnson. 1990. "Ex Post Liability for Harm Versus Ex Ante Safety Regulation: Substitutes or Complements?" *American Economic Review* 80 (September): 888–901.

Lyon, Randolph M. 1989. "Transferable Discharge Permit Systems and Environmental Management in Developing Countries." *World Development* 17, no. 8: 1299–1312.

Mahar, Dennis J. 1989. *Government Policies and Deforestation in Brazil's Amazon Region.* Washington, D.C.: World Bank.

Margulis, Sergio. 1992. "Back-of-the-Envelope Estimates of Environmental Damage Costs in Mexico." Working Paper 824. World Bank, Latin America and the Caribbean—Country Department II, Agriculture Operations Division, Washington, D.C. Processed.

McCleary, William. 1991. "The Earmarking of Government Revenue: A Review of Some World Bank Experience." *World Bank Research Observer* 6, no. 1: 81–104.

OECD (Organization for Economic Cooperation and Development). 1975. *The Polluter Pays Principle.* Paris.

Opschoor, J. P., and Hans Vos. 1989. *The Application of Economic Instruments for Environmental Protection in OECD Member Countries*. Paris: Organization for Economic Cooperation and Development.

Pearson, M., and Smith S. 1990. "Taxation and Environmental Policy: Some Empirical Evidence." Commentary 19. Institute for Fiscal Studies, London. Processed.

Pigou, A. C. 1920. *The Economics of Welfare*. London: Macmillan.

Plourde, Charles, and David Yeung. 1989. "A Model of Industrial Pollution in a Stochastic Environment." *Journal of Environmental Economics and Management* 16: 97–105.

Posner, Richard A. 1986. *Economic Analysis of Law*. 3rd ed. Boston: Little, Brown.

Repetto, Robert, and Malcolm Gillis, eds. 1988. *Public Policies and the Misuse of Forest Resources*. Cambridge and New York: Cambridge University Press, with World Resources Institute.

Ringleb, Al H., and Steven N. Wiggins. 1990. "Liability and Large-Scale, Long-Term Hazards." *Journal of Political Economy* 98, no. 3: 574–95.

Roberts, Marc J., and Michael Spence. 1976. "Effluent Charges and Licenses under Uncertainty." *Journal of Public Economics* 5: 193–208.

Russell, Clifford S. 1990. "Monitoring and Enforcement." In Paul R. Portney, ed., *Public Policies for Environmental Protection*, Washington, D.C.: Resources for the Future.

Sandmo, Agnar. 1975. "Optimal Taxation in the Presence of Externalities." *Scandinavian Journal of Economics* 77: 86–98.

———. 1976. "Direct versus Indirect Pigouvian Taxation." *European Economic Review* 7: 337–49.

Schramm, Gunter, and Jeremy J. Warford, eds. 1989. *Environmental Management and Economic Development*. Baltimore: Johns Hopkins University Press.

Sebastian, Iona. Forthcoming. "Issues in Urban Air Pollution: Mexico City Diagnostic Study." Environment Department Working Paper. World Bank, Washington, D.C. Processed.

Seskin, Eugene P., Robert J. Anderson, Jr., and Robert O. Reid. 1983. "An Empirical Analysis of Economic Strategies for Controlling Air Pollution." *Journal of Environmental Economics and Management* 10: 112–24.

Spulber, Daniel F. 1985. "Effluent Regulation and Long-Run Optimality." *Journal of Environmental Economics and Management* 12: 103–16.

Thomas, Vinod. 1981. *Pollution Control in São Paulo, Brazil: Costs, Benefits and Effects on Industrial Location*. Staff Working Paper 501. Washington, D.C.: World Bank.

———. 1985. "Evaluating Pollution Control: The Case of São Paulo, Brazil." *Journal of Development Economics* 19: 133–46.

Tietenberg, T. H. 1988a. *Emissions Trading: An Exercise in Reforming Pollution Policy*. Washington, D.C.: Resources for the Future.

———. 1988b. *Environmental and Natural Resource Economics*. 2nd ed. Glenview, Ill.: Scott, Foresman.

Tybout, R. A. 1972. "Pricing Pollution and Other Negative Externalities." *The Bell Journal of Economics and Management Science* 3, no. 1 (Spring): 252–66.

———. 1973. "Pricing of Pollution: Reply." *The Bell Journal of Economics and Management Science* 4, no. 7: 320–21.

U.S. Congress. 1990. *Clean Air Act Amendments*. Report S.1630. 101st Cong., 2nd sess.

Weitzman, Martin L. 1974. "Prices vs. Quantities." *Review of Economic Studies* 41: 477–91.

Whalley, John, and Randall Wigle. 1991. "Cutting CO_2 Emissions: The Effects of Alternative Policy Approaches." *Energy Journal* 12, no. 1 (January): 109–24.

Wijkander, Hans. 1985. "Correcting Externalities through Taxes on/Subsidies to Related Goods." *Journal of Public Economics* 28: 111–25.

World Bank. 1991. *Lessons of Tax Reform*. Washington, D.C.

Yan, Chiou-Shuang, Ah-Min Chung, Edward C. Kaziara, and Andrew G. Verzilli. 1975. "Air Pollution Control Costs and Consumption Pattern Effects: A Regional Analysis." *Journal of Environmental Economics and Management* 2: 60–68.

Yohe, Gary W. 1979. "The Backward Incidence of Pollution Control—Some Comparative Statics in General Equilibrium." *Journal of Environmental Economics and Management* 6: 187–98.

Yu, E. S. H., and C. A. Ingene. 1982. "The Backward Incidence of Pollution Control in a Rigid Wage Economy." *Journal of Environmental Economics and Management* 9: 304–10.