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Choosing Policy Instruments for Pollution Control

A Review

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Such realistic problems as limited monitoring and enforcement capacity can often render the standard recommendations on pollution control ineffective, particularly in developing countries. Taxes (and subsidies) on inputs and outputs can in some cases be effective in reducing pollution — even if they imperfectly mimic pollution taxes.

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This paper — a product of the Public Economics Division, Country Economics Department — is part of a larger effort in PRE to analyze environmental problems and policies in developing countries. Copies are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Ann Bhalla, room N10-055, extension 37699 (60 pages).

Eskeland and Jimenez review the theoretical and empirical literature on policy instruments for pollution control, emphasizing constraints on policy choices that prevail in many developing countries. They examine how a given reduction in emissions can be achieved at the lowest possible cost.

Under some restrictive assumptions common in welfare economics, a pollution tax gives perfect incentives for reducing pollution.

Under the same assumptions, a system of tradable emission permits also allows efficient emission reduction — in contrast to the more common command-control regulatory regimes of source-specific emission constraints. Source-specific constraints usually achieve the same degree of abatement at a higher cost.

But these standard assumptions are particularly inappropriate in developing countries. First, transfer mechanisms are not well developed, with the consequence that both the public revenue and income for the poor are valued at a premium. Second, monitoring and enforcement capacity can be severely constrained, with the result that sophisticated instruments such as pollution taxes and tradable permits cannot play a major role.

The authors discuss recommendations that take these and other problems into account. An example is that policies relying heavily on monitoring and enforcement make less sense in developing countries than in industrialized market economies. Developing country agencies may not have the capacity to monitor and to tax emissions or damages directly. Taxes and subsidies on inputs and outputs can then, under certain circumstances, be effective in inducing abatement, even if they imperfectly mimic taxes on monitored emissions and damages. When monitoring and enforcement capacity is constrained, the better policy may be fuel taxes based on assumed emissions — or taxes or subsidies for equipment with different emissions characteristics. Indirect policy instruments like these can work well if they affect the profitability of abatement options without affecting other choices.

Any reform in developing countries must take into account how it affects the most vulnerable groups in society. For instance, poverty considerations may restrict the use of high fuel taxes if the poor spend much of their income on fuels. And privileged groups are often strong in developing countries and may block otherwise well-designed policies. These considerations are relevant when mechanisms for compensation are not well developed.

Eskeland and Jimenez emphasize the need to incorporate analysis of behavioral responses in the design of intervention instruments. Exploiting flexibility among consumers and producers is a key to containing environmental costs. Schemes that encourage self-compliance, such as deposit-reform systems, should be considered.

CHOOSING POLICY INSTRUMENTS FOR POLLUTION CONTROL:

A REVIEW

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1. INTRODUCTION

Some pol` ion problems can be serious at early levels of development, for instance because of lack of sewers. However, most pollution problems tend to become more pressing as countries develop before appropriate policies are developed to control them.[1] One reason is that virtually all economic activity results in some environmental degradation, but it may not become problematic until a certain absorptive capacity is reached. A second reason is that protection of the environment, as a public good, requires a level of institutional and administrative capacity that has to be developed.

Health impacts, particularly in urban areas, are starting to be reflected in morbidity and mortality trends. For example, in the 1980s, air pollution was shown to have a significant impact on mortality in Sao Paulo (Thomas 1981, 1985). In Cubatao, evacuation has been ordered several times, when air toxicity has reached levels a dozen times higher than acceptable thresholds (Anderson 1990). Untreated and open sewers have long been known to be sources of health risk, but attention has also recently been drawn to contamination of groundwater. In Mexico, drinking water related illnesses account for 75 deaths in 100,000 in the age group 1-4 (Pearce, 1990). Recent studies carried out for the Bank in Poland and Hungary (Walsh 1990, Hertzman, 1990a, 1990b) link adverse health effects to pollution of air, water and soil. Often the poor will be the first to suffer, since they have little political clout and few alternatives; in the cities, they typically live in areas where health risks are created by air and water pollution, sewerage and waste problems.

Aside from the impact on health, there are also effects such as the loss of agricultural output and biodiversity, and increased depreciation of man-made assets such as buildings and machinery. Many places, water pollution is seen to

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[1] Since sector shares and processes change, some environmental problems may, in principle, become less acute with growth, even in the absence of control policies. When effective control policies are implemented, the environment may improve even when economic activity grows.

be potentially costly in terms of the returns to tourism (for example, the Philippines, Dixon and Hodgson, in 1983).

Although rigorous studies do not exist, there is casual evidence that pollution control policies in developing countries are inefficient. This indicates that environmental improvements should be achievable at comparatively low costs. Often, regulations are not in place or they are inappropriately designed or enforced. In addition, economic policies that are unrelated to the environment nevertheless affect it, and often adversely.[2]

This paper presents, with the help of a literature review, the design of cost effective interventions to protect the environment from excessive pollution in developing countries. The concept of intervention is motivated by the typical explanation for environmental problems in economic theory--external effects. If the parties who are affected negatively by an activity cannot themselves influence the activity, the market fails, since their interests are ignored when decisions are taken. Then, there is a role for authoritative intervention to affect the activity directly or indirectly. A cost effective set of policy instruments is a set that can achieve a targeted emission reduction at the lowest possible total cost. The aim of the paper is to review the relevant theoretical and empirical economic literature (which, when applied is almost solely on developed country examples), in order: (a) to distill the principal lessons and evaluate general rules of thumb and (b) to identify gaps that need to be filled in order to make them more accessible and relevant to developing countries.

This paper defines broadly the range of policy instruments that can be used to address pollution problems in developing countries. It includes instruments that have traditionally been in the realm of public finance, such as

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[2]Mahar (1989) and Binswanger (1989) conclude that deforestation in the Amazon is accelerated by sectoral policies such as tax incentives; Repetto and Gilles (1988) provide similar arguments over a wider range of examples; Kosmo (1989) maintains that subsidies to energy, water and raw materials exacerbate pollution problems in countries such as Algeria, Egypt, Yugoslavia and Turkey; Baratz (personal communication) points out that the policies of low import tariffs on used vehicles results in unnecessarily high pollution (and fuel bills) in many LDCs.

taxes, prices and subsidies.[3] But it also covers regulations and (briefly, her instruments designed to affect the amount of pollution or to mitigate its damage. As described in Table 1, these interventions can be categorized as (i) market based incentives (MBIs) that affect the incentives of private agents, (ii) command and control (CAC) instruments that regulate activity by source specific constraints and (iii) government expenditure on clean-up or enforcement. We find it useful also to distinguish between those instruments that are directly associated with the amount of damage created or pollutants emitted, and those addressing pollution indirectly via related variables such as inputs and outputs.

Table 1. A Taxonomy of Policy Instruments

	Direct Instruments	Indirect Instruments
Market Based Incentives: (MBIs)	Effluent Charges, Tradeable Permits, Deposit Refund Systems	Input/Output taxes and subsidies, Subsidies to substitutes and to abatement inputs.
Command and Control: (CAC)	Emission Regulations (source specific, non-transferable quotas)	Regulation of Equipment, Processes, Input and Output
Government Production or Expenditures:	Purification, Clean-up, Waste Disposal, Enforcement and Agency Expenditures	Technological Development

A direct instrument is addressing the level of damages or emissions directly, whereas indirect instruments work via other variables.

Conditions to be Emphasized in Developing Country Policy Analysis

[3]Regulations do also, if enforced, provide incentives that affect behavior. We will, however, according to tradition, use the notions command and control (CAC) and regulation of approaches that specify the actions of each subject (or category of subjects) as legal or illegal, as compared to open, flexible instruments that leave more choice to the subjects (see Section 2).

Developed and developing countries alike now find that they want to manage their environmental assets with greater prudence. But developing countries confront constraints and challenges that require special attention in the design of pollution control policies. Thus, while using the standard assumptions (competitive markets, costless transfers, certainty, full information) as a starting point, we analyze such conditions as are discussed below.

The *scarcity of public funds* in many LDCs, the ***need to protect the poor** and considerations of political economy* all indicate that transfer mechanisms are not well developed. Efficiency criteria then need to be supplemented by considering the distributive impact of different policy instruments. ***Weak** institutions* may severely hamper access to *information* and ***the ability to monitor** damages* and *implement sophisticated schemes*. Under these conditions, it is necessary to analyze what can be achieved through imperfect incentives based on blunt, indirect instruments, for instance by applying presumptive pollution taxes to fuels. Further, the frequently applied assumption of a ***competitive market** structure* may be less realistic (but not necessarily less useful as a base line) in an LDC context than in an industrialized market economy. The role and functioning of instruments such as taxes and quantitative regulations will of course not be the same in the presence of *market power, soft budget constraints and administered prices*, as under the standard assumptions.

Some "typical" developing country characteristics are not dealt with explicitly. For instance, it may be claimed that environmental protection is a luxury good, and that LDCs cannot afford policies that may possibly constrain growth and international competitiveness.[4] Therefore, we concentrate here on

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[4]We do not present guidelines or results on benefit estimation here, but we caution against a general conclusion that emission control is unaffordable and unnecessary. In many developing countries, poor people without the means to move or to afford protection measures are exposed to extraordinary health risks. Counterarguments can easily be made that emission control is an inferior good; once people have moved to other areas, water is treated and sewage is piped, emission control is less necessary. We do believe, that some abatement will often be desirable even if the pressure on the environment is low, provided the cheapest abatement options are selected.

cost effective intervention, in order to show how to achieve a given emission reduction at the lowest possible cost. These results are useful at any level of desired pollution control, whereas assessing the optimal level of control would require that marginal benefits be estimated and compared to marginal costs, a task which is not discussed in this paper.

The analysis will be accompanied by empirical evidence on the cost efficiency of alternative instruments in different situations. Evidence on the relative cost effectiveness of different instruments will be taken from developing countries to the extent it is available, but most quantitative empirical evidence of this sort has to be drawn from developed countries.

To limit the scope of this paper, we treat pollution control policies, but not policies to address other environmental problems, such as soil erosion, deforestation, desertification or other natural resource problems. Many of the principles we present, however, broadly relate to the problem of correcting for external effects, and can be applied and to these other problems as well. Also, we focus on domestic problems and do not deal explicitly with trans-national (acid rain) or global pollution externalities (climate change/ozone depletion). Finally, of the instruments listed (in Table 1), we do not concentrate explicitly on government production or expenditures to clean the environment.[5]

Outline

The analysis starts with a set of underlying assumptions that allows for the simplest treatment, and most readers will recognize the result that a pollution tax (or its close relative, tradeable permits) is recommended on efficiency (welfare) grounds. Section 2 thus introduces basic concepts such as the rationale for government intervention when there are negative externalities, and the results of intervention instruments under very restrictive, simplifying assumptions. Although these results are widely cited, many of the recommendations change when the assumptions are relaxed to conform more closely

[5]Public expenditures on the environment follows traditional analyses of the optimal provision of public goods (see for instance Atkinson and Stiglitz 1980), as well as footnote 21.

to conditions that we are likely to find in developing countries. We subsequently extend the analysis of cost effective intervention from the simplest case to more realistic ones, emphasizing the role of conditions that are prevalent in developing countries.

Section 3 discusses how the choice of instrument is affected when one allows for: (i) distortive and costly public revenue generation; (ii) a limited capacity to monitor emissions; (iii) uncertainty about the benefits and costs of control; and (iv) a noncompetitive market structure. Section 4 addresses two aspects of distributive implications--the protection of the poor, which is of concern from a welfare perspective, and the effects on groups with vested interests, which are relevant for the likelihood of policy adoption. The paper ends with a concluding section and an outline of further research.

2. BASIC CONCEPTS

This section outlines the economic rationale for government intervention aimed at addressing pollution problems, and presents some basic results about the choice of policy instruments. These results are generally well known but are derived from quite restrictive assumptions. Section 3 will discuss what happens to the basic results when the assumptions are relaxed.

The Rationale for Government Intervention

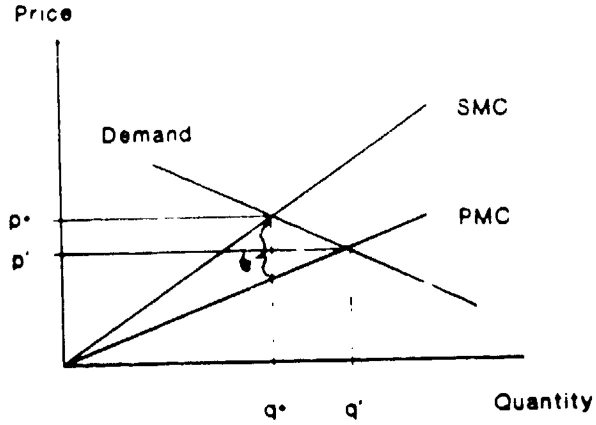
The efficiency argument in favor of public intervention to mitigate pollution problems is well established in the theoretical literature.[6] The traditional justification is the need to correct for external effects. An external effect occurs when the welfare of a household (or the costs of a firm) depends not only on its own actions, but also on the actions of others. Thus, polluting activities are often seen as the prime example of a negative externality.

When there are no externalities, the planner would want to allocate resources to different uses in the same way as a (hypothetical) perfectly competitive market would, thus equating marginal benefits with marginal costs in all markets. When there are pollution externalities, the market mechanism would fail to induce the polluter to consider the costs of its activity on others. The free market would result in pollution in excess of optimal levels, since an industry would pollute until private marginal benefits equalled private marginal cost (see Box 1 for a diagrammatic exposition). The interests of those hurt by pollution, as expressed in social benefits and costs, do not influence the polluter. Policies to address the problem aim either to regulate the level of pollution at the source or to change prices or regulations so as to increase the private costs of polluting. The choice between these two types of policies will be discussed in the next sub-section.

[6] See Baumol and Oates (1988) and Tietenberg (1988) for standard and comprehensive textbook treatments.

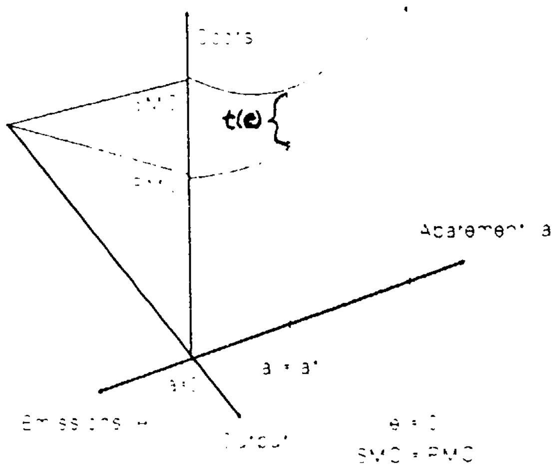
Box 1: Correcting for Externalities

Box Figure 1a



Assuming a fixed relationship between output q and emissions, the rationale for intervention is illustrated in Box figure 1a. Social marginal costs (SMC) equals private marginal costs (PMC) plus the costs to society of emissions. Without intervention, the market settles for the price p' and output q', resulting in excessive pollution. Applying a tax t on emissions or output, in this case equivalent, or a tradeable quota, the socially optimal quantity q* can be induced.

Box Figure 1b



Usually, cleaner ways of producing are available as in Box Figure 1b, where both abatement a and output q is to be chosen. The right part of the figure extends Box Figure 1a with an axis denoting abatement, and a* denotes optimal abatement. Optimal abatement and output can then be induced by an emission tax t(e) or tradeable emission permits, but not by taxing or constraining output.

Are public intervention policies necessary to correct for externalities? According to the Coase proposition (Coase 1960), there is no efficiency reason for a government to be involved in the regulation of pollution damage except to assist in enforcing property rights. Pollution will be curbed either when the victims bribe the polluter or when the polluter bribes the victims, depending upon who holds the initial rights to clean air or water. In either case, as long as negotiations are not costly, the socially optimal amount of pollution will be the result, since the polluter will effectively face marginal conditions comprising the full social cost.

When there are few polluters and victims and when the number of beneficiaries from an agreement is given, the Coase proposition may indeed be valid, so that negotiations can provide for the internalization of externalities. Dixon and Hodgson (1988) cite an example in the Philippines where soil sediments caused by a single logger threatened the development of tourism in a bay. In Turkey, farmers have been awarded damages in court when emissions from factories have hurt their crops. The latter example shows that if the right to an unpolluted environment is established and enforced, it can indeed give incentives to abatement. Particularly when stakeholders are easily identified, a case can be made that intervention is unnecessary for efficient outcomes, although credible law enforcement (a public good) is often a necessary ingredient.[7]

The validity of the Coase proposition rests on two critical assumptions. One assumption is that transaction costs are zero or negligible. In practice, these costs will increase with the number of polluters and victims. In Mexico City, for example, there are twenty million consumers, 2.5 million motor vehicles and 30,000 industries; it hardly seems feasible that these economic agents will conduct efficient negotiations without an intervening authority. Moreover, to

[7]The role of liability under an uncertainty is treated in Section 3.3.

be efficient in the long run, the agreement must accommodate entry and exit[8].

A second assumption is that negotiation will be successful and that agreements can be enforced. In practice, negotiation is a difficult process and may not lead to a mutually beneficial agreement. This is especially so because the parties have an incentive to conceal information.[9] Private negotiation may not be successful because a party has an incentive to free-ride either by not revealing willingness to pay or by breaking the agreement.[10]

Once either of these assumptions is violated, public intervention may be the only efficient solution. Market prices are not the only mechanisms in place that govern resource use, however, and therefore a careful examination is warranted, particularly in developing countries: traditional management of common property resources in a rural setting, for instance, may already incorporate disciplinary elements that correct for local externalities.[11] These mechanisms will often become less efficient, however, as population density and mobility increase, and externalities extend across greater distances and longer time periods.

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[8]On the long run efficiency of the negotiated solution with well defined property rights, see H.E. Frech III (1973) and R.A. Tybout (1972) and (1973). Efficiency can be maintained if those who leave and arrive can charge or be charged for leaving and arriving.

[9]See, on incentive compatible demand revelation Groves and Ledyard (1977) and Green and Laffont (1979). Farrel (1989) uses a simple approach to show that an intervening bureaucrat may be more efficient than negotiations, even when the bureaucrat is limited to poor information and there are only two agents.

[10]Many mechanisms appear to be voluntary but require authority to define rules and enforce them. A Lindahl equilibrium (Johansen 1963) is a set of prices (taxes) at which equilibrium demands are efficient, but these are prices that have to be imposed on trades. Since the pollution problem is one of a prisoner's dilemma (resulting from free-riding), efficiency can always achieved if individual preferences are known and binding agreements can be made. Of course, such an agreement need not be in terms of quantities, but may be in terms of (Lindahl) prices. Still, however, trades and terms have to be supervised (and taxed or subsidized), so the need for authority is not relinquished.

[11]Magrath (1989) and Dasgupta and Maler (1990) provide references.

Basic Results about Choice of Instruments

Given that intervention is required, what form should it take? Suppose that the government wants to reduce the damages from pollution by reducing total emissions from a variety of sources to a lower threshold level. Some of the basic choices faced by the government are:

- Market based incentives (MBIs) versus command and control (CAC).
- Among MBIs, price based versus quantity based instruments (in other words, taxes and subsidies versus tradeable permits).
- What the rate for MBIs should be and whether taxes or subsidies should be used.
- How tradeable permits should be priced and distributed.
- Whether beneficiaries should be charged and victims compensated.

To establish a basis for later comparison, we make the following restrictive assumptions: (i) that the same amount of emissions from different sources have equal external costs; (ii) that transferring revenue to or from the public sector is not in itself costly; (iii) that the costs of monitoring damage and emissions are low; (iv) that there is no uncertainty about the costs and benefits of pollution control; and (v) that a competitive market structure prevails. Towards the end of this section, we study intervention when emissions are not uniformly dispersed.[12] In subsequent sections, we relax each of the other assumptions and go on to discuss the role of distributive objectives.

MBIs versus CAC. In the case of uniformly dispersed pollutants, ambience quality can only be improved (or protected) by curbing overall emissions. Command and control (CAC) simply imposes regulations by fiat; constraints regarding emissions of pollutants are defined for each source and trading among sources of the right to pollute is not allowed. Most countries have relied predominantly on CAC by setting and enforcing standards for

[12]Pollution is uniformly dispersed when the external costs to society are independent of the location of the source. One example is greenhouse gases, such as CO_2.

equipment, processes or emissions, which means that an activity is legal only if it satisfies certain requirements.

Market based incentives (MBIs) provide an alternative route to the same ambience quality by encouraging polluters to change their behavior through altering the private costs of polluting. MBIs include a broad range of instruments. Their most obvious forms are environmentally related prices, which can be implemented through taxes on emissions or subsidies to abatement. A system of pollution permits, under which a polluter is required to hold permits for the amounts emitted, is also included among MBIs if polluters are allowed to trade permits among themselves.[3]

Although CAC and MBIs can achieve the same ambience quality, MBIs generally provide it at lower cost; in other words, MBIs are more cost effective. Source specific constraints allow marginal costs to vary among polluters, which implies that total costs of abatement are not minimized. In order to minimize total abatement costs (across all activities or locations), no polluter should be asked to reduce emissions if another can do so at lower costs (see Box 2 for a graphical presentation).[4]

Cost effective abatement can be achieved by issuing permits that can be traded (Dales, 1968 is one of the early proponents of this point). A polluter with high costs of abatement would purchase permits, while one with cheaper abatement options would prefer to reduce emissions. Cost effective abatement can also be achieved by a pollution tax. This allows each source to decide whether to pay the tax or to undertake additional abatement, and each source will abate

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[3]Emission quotas and permits are here used synonymously; a quantity instrument is a more general term, comprising constraints for any kind of variable.

[4]One general criterion defining MBIs should be that it allows agents to equalize the shadow prices of environmental constraints between polluters. This means, effectively, that polluters face only one overall constraint, which regulates behavior in exactly the same way as a pollution tax. The total costs of satisfying one overall constraint is always lower than or equal to those of satisfying many, if the constraints add up to the same. This definition thus explains the theoretical result that MBIs are always cheaper than CAC.

provided that marginal abatement costs do not exceed the tax rate. The only way for CAC to minimize society's cost are if the regulator knows and takes into account each firm's abatement costs. That would be a very difficult job for any government, especially one in a developing country where there is likely to be many heterogenous polluters, often in an undocumented informal sector, and a weak public administration. A major advantage of MBIs is thus that they require less information than CAC to be a cost efficient. This "information economy" of market based instruments relieves the regulator from the need to quantify individual abatement costs; these are known to the polluters, and each polluter will use this information when exposed to MBIs. However, both CAC and MBIs require the regulator to have estimates about aggregate costs and benefits of abatement in order to avoid excessive or suboptimal overall pollution control.

The full set of regulations affecting emissions can consist of both CAC and MBI instruments, and applied regulations will often use both types of tools. In the U.S.,for example, some limited opportunities to "trade" within a CAC framework has been allowed in an attempt to benefit from some of the savings MBIs would offer (see Box 3).

Empirical investigations have strongly supported the theoretical case for MBIs by reporting major costs savings relative to applied CAC. Tietenberg (1988) reviews nine studies where applied CACs and MBIs are calibrated to reach the same ambience level. For seven of these, the ratio of MBI costs to CAC costs is 1/4 or lower. For two of the studies, the ratio is 1/14 or lower.

Prices versus quantity based MBIs. Under the restrictive assumptions in this section, price based MBIs such as taxes and quantity based MBIs such as tradeable permits have exactly the same effect.[15] They result in the same level of emissions and economic costs (see Boxes 1 and 2 for graphical expositions). A uniform emission tax will have the same incentive effects as an emission quota if the quota can be shared within the industry according to willingness to pay.

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[15]The equivalence breaks down under uncertainty about abatement costs, which is treated in the next section.

Both minimize overall abatement costs, as high-cost abaters will choose to pay the tax or will outbid low-cost abaters for shares of the quota.

Although taxes and permits that can be traded freely are conceptually equivalent, some analysts have argued that, for administrative reasons, tradeable quotas may be preferable to tax or price instruments (Baumol and Oates 1988). First, in order to find the tax that will result in the desired ambient quality, the public authority may need several rounds; set a price, measure resulting ambience quality, adjust the price and so on. This may be a costly process, particularly in inflationary environments when such fees must be frequently adjusted.[16] Second, permits may be easy to implement, since they make it possible to introduce controls without increasing the costs of existing firms.[17]

But the administrative arguments can work both ways. 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, if emissions can be addressed effectively via input taxes, this is likely to be easier to implement than a completely new scheme such as a permit trading.

Setting price based MBIs. If governments use a pollution tax to protect ambience quality, they should select a base and a rate so that the external cost of the activity is internalized. Such an instrument is often called a Pigouvian tax.[18] The appropriate base for the tax should be the damage caused or a close

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[16]The problems of uncertainty about response to policies, and of "sticky" instruments, are treated more thoroughly in Section 3.

[17]The "new source bias" (stricter controls for new plants) is often interpreted as incumbents being able to influence regulations to their own advantage, and thus in appropriating rent (Baumol and Oates 1988, Hahn, 1989). Under CAC, however, a new source bias may actually be efficient if (and only if) technology is more flexible ex ante than ex post. Insight into such cost aspect is redundant for efficiency under MBI.

[18]Since A.C. Pigou's (1920) seminal contribution, "Pigouvian taxes" has been the expression used for taxes to discourage activities with negative externalities.

Box 2. Market-based Incentives (MBI) are Always Cheaper Than Command-and Control (CAC)

The value of equating the costs across sources can be illustrated diagrammatically in figures 2 and 3. Figure 2c illustrates a supply curve resulting from (horizontal) summation of marginal cost of the individual firms in 2a and 2b. The unregulated market establishes the price p′ (figure 2c), and equalizes private marginal costs (PMC) between producers, so that output q′ is produced at minimum costs. An emission tax equal to the marginal social cost of emissions would induce the market to establish the efficient output level q*, and distribute production efficiently between the two firms, q_1^*, q_2^*. In Figures 3a and b, we have assumed that the planner does not know the individual firm's marginal costs, and he has given the firms equal quotas that add up to the social optimum. As is seen in 3, the planner will reach his output target but production is inefficient since firm 1 is producing units which firm 2 could have produced at a lower cost. Only with luck or knowledge of individual cost functions could the planner have avoided these welfare losses when applying untradeable quotas (CAC).

Figure 2: A tax is used to induce socially optimal quantity q*

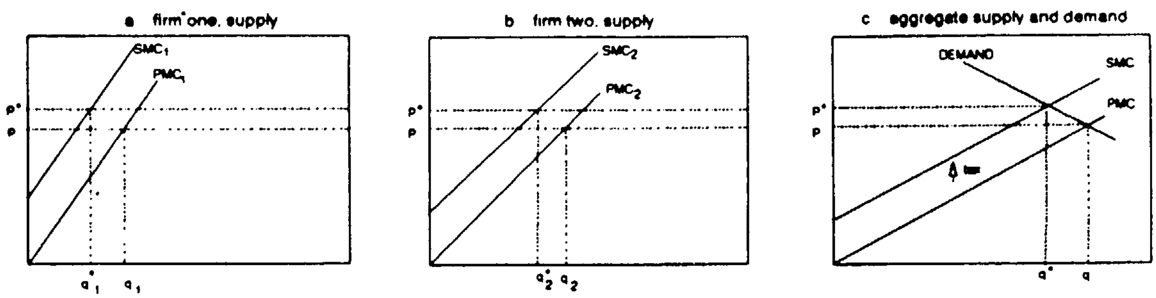
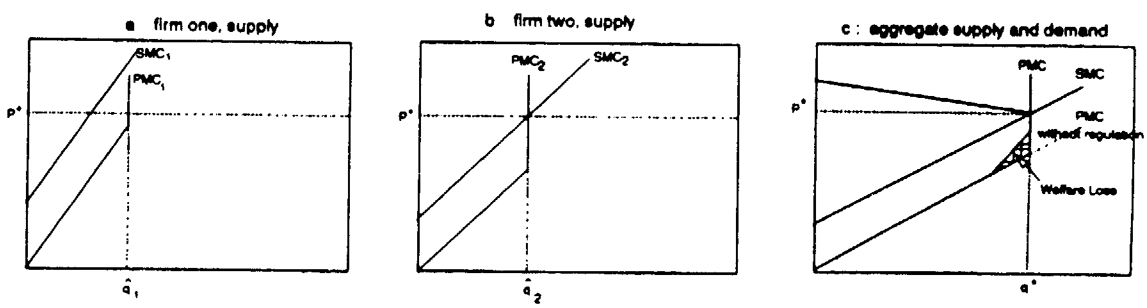


Figure 3: Quotas $q_1 + q_2 = q^*$ are used to induce the socially optimal quantity q*



proxy for it, such as emissions.[19] An example could 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 emissions into water in Germany and on solid waste in Denmark.[20]

What determines the rate of the tax? With a fixed relationship between output and damages, the rate of corrective tax on the polluting good will be the marginal rate of substitution in consumption between the externality and the commodity times the number of individuals affected by the externality[21]. Thus, the higher the damage created per unit of satisfaction due to consumption of the good in question, or the higher the number of people affected, the higher will be the corrective tax. The fact that this tax fully internalizes the external effects can be seen by deriving consumer demand under the resulting relative prices; the consumer adjusts as if he himself faced all the damages his consumption creates. Note that there is no need to tax complements or to subsidize substitutes when the tax on the polluting good fully internalizes the externality.

The Pigouvian incentive could be either as a tax on pollution or as a subsidy to abatement. In the short term, the incentive effects can be the same. In the long term, when entry and exit can be affected, a tax will normally be preferable. The symmetry is broken because firms may be induced to enter a

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[19]The relationship between damages and emissions often varies by the location of source. This is discussed in the next subsection.

[20]Whalley and Wigle (1989) and Opschoor and Vos (1989).

[21]The proportional tax rate will be $\frac{t_m}{P_m} = -n \cdot \frac{u_{m+1}}{u_m}$, where P_m is the consumer price, u_{m+1} is the marginal utility of the externality (negative), u_m is the marginal utility of consuming the externality creating good m and n is the number of individuals affected by the externality. The familiar formula reminds us that the problem posed is one of optimal provision of public goods: the *sum of the marginal rates of substitution* in consumption is to be equal to the marginal rate of transformation (Oakland, 1987, for an exposition of the argument).

subsidized industry and the net effect would be a higher than efficient level of pollution.[22]

Quantity based MBIs: distributing and charging for tradeable permits. The initial distribution of pollution permits does not have implications for efficiency as long as they can be traded. Firms or individuals for whom it is costly to reduce emissions can acquire permits if they are held by others that do not need them that badly. The price reigning in the market for permits will give incentives to abate in the same way as a pollution tax would.

While permits could be auctioned and thus distributed initially according to willingness to pay, it is often suggested that they be distributed free of charge. The revenue and distributive implications of that choice are dealt with later in this paper, but some caution is necessary. If permits are distributed at a charge lower than the market price, the recipients receive a privilege, and it is necessary to ensure that this does not provide undesired incentives in itself. For instance, a free flow of permits to a firm should not be conditional on the firm's behavior, since such a condition could distort other choices or prevent the permits from being sold to others who could use them more efficiently (e.g. allocation of permits should not be dependent on the firm still being an active producer).[23] If cheap distribution is desired initially in order not to shock implicit property rights, one could increase the charge gradually so that a less discriminatory regime is eventually established.

Charging Beneficiaries/Compensating Victims. The question of compensating victims is often raised under a mixed agenda that includes

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[22]Let e_i be emissions from a firm or an individual i, let $c(e_i)$ be external costs related to emissions and $t(e_i)$ be an incentive scheme; t is taxes paid (if positive) or subsidies received (if negative). Efficiency of incentives requires that $t' = c'$ where t' and c' are t and c differentiated with respect to e_i. This condition allows for a tax on emissions or a subsidy to abatement. However, if t(e) is to be faced by all individuals, practicality recommends that $t(0) = 0$. Then it is clear that $t(e)=c$, so that emissions should be taxed rather than abatement subsidized.

[23]The Coase proposition states neutrality of *initial* distribution of rights, which is by definition unaffected by behavior.

efficiency as well as equity considerations.[24] An efficient incentive scheme must give proper inducement to any action that can reduce external costs, whether it is to reduce own emissions, to reduce consumption of a polluting commodity, to engage in recycling or clean-up activities or to take protective measures (like moving).

Thus, from an efficiency point of view, it is not necessary to compensate victims or to charge beneficiaries. It would be possible to charge beneficiaries or compensate victims for other reasons without reducing the efficiency of the incentive scheme if these transfers could be made independent of activities that themselves affect the level of external costs. Compensation should then be designed so as not to give incentives to people to become a victim (or to suffer more). Charging beneficiaries can easily create free rider problems, for instance if a citizen can benefit freely by pretending not to be interested.

Compensation necessarily plays a major role in schemes without (significant) intervention, both in the theoretical Coasean scheme and under negotiations/common law liability. The zero sum budgets of these programs imply that any charge paid will be received by another party, and this can typically cause problems in practical situations (incentives to become a victim, to take inadequate protection measures or to avoid being counted among beneficiaries). In the theoretical situation described by Coase, there is no potential for inefficiency, since the options and preferences of each agent are assumed to be known with certainty. Often, mere numbers will indicate that the incentive problems of compensating victims are miniscule. For instance, it is difficult to imagine that revenues from pollution taxes would excessively stimulate migration to a city, even if the revenues were used solely within city boundaries.

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[24]Efficiency aspects are dealt with thoroughly in Baumol and Oates (1988).

<u>**Dispersion and the Availability of Differentiated Instruments**</u>

Most pollution problems have an important spatial dimension. While we have chosen not to treat the jurisdictional issues here,[25] cost efficient strategies often require differentiated instruments even within relatively small regions.

Pollutants are usually not uniformly dispersed but are concentrated in some pattern around the source and downwind or downstream. The result is that some sources pollute locations that are more vulnerable at the margin than those polluted by other sources. These differences in damages per unit of emission depend on where the sources are located and on the dispersion characteristics of their emissions (determined by such variables as stack height, speed and temperature of flow, etc.) as well as on the nature of the site being polluted.

For many major air pollutants, the benefits of emission reductions have effectively been seen as negligible in vast rural areas, and the application of uniform emission charges (or one-for-one tradeable emission permits) in zones comprising both urban and rural areas would not then be cost effective.[26] With uniform emission charges, improvements in polluted locations would require unnecessary abatement from many sources whose emissions do not pollute the "hot spots". In these cases, the least cost program requires that abatement for each source depends on whether its emissions will pollute vulnerable locations or not. Such a program can be implemented by instruments related to the damage that each

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[25]Ideally, spatially differentiated instruments should be available to reflect the spatial nature of the pollution problem, but jurisdictional issues would usually involve constraints on instrument choice. See Siebert (1985) for a general treatment of spatial aspects, and Pearce (1990) for a discussion of the Mexican case.

[26]We here use the rural/urban dimension to illustrate differences in marginal damages per unit of emissions. The principle, and the need for differentiated instruments, is of course valid for any pattern of nonuniform damages (or, equivalently, benefits). One area A may be more vulnerable than B in principle (biotopes, crops, children), but less important to protect in practice if higher present pollution loads in B makes the marginal damage in B higher.

source causes. Such "damage" instruments can be envisaged as emission charges differentiated according to the ratio of damages to emissions.

Damage differentiation for permits is achieved by an ambience permits scheme (APS). Under an APS, a polluting source must hold a different permit for each location reached by its emissions.[27] The value of each type of permit will depend on the vulnerability of the location to the emissions. The APS is ideal from a theoretical point of view, but may be costly and difficult to implement, given that there will be many interrelated markets for the various permits.

An emission permit system (EPS) treats all emissions from sources within a zone equally, while banning trades between zones so that each source needs to purchase only one type of permits. An EPS cannot generally be cost minimizing since, within zones, differences in damages between sources are ignored and, between zones, it relies on the initial distribution of permits. It can, however, be fairly efficient if a region is divided into zones that are internally homogeneous with respect to the ratio of damages to emissions. Optimal zoning would trade off the costs of uniformity within large zones and the costs of banning additional trades associated with smaller zones.

In essence, differences in damages per unit of emissions means that unlimited trading of permits is not desired. Between zones, permits need to be distributed carefully, since sources are barred from solving problems of misallocation through trades (see Box 3 for some applied limited trading schemes).

If a region contains polluters with very different ratios of damages to emissions, differentiating instruments accordingly can yield significant cost savings. Consequently, the costs of applying uniform emission charges or permits without zoning will also be high. Atkinson and Tietenberg (1982) calculate that

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[27]A region is subdivided by a grid, with a sensor for ambience quality in each grid cell. A dispersion model calculates how many permits polluter i needs for grid cell j for each unit he emits. If i wants to pollute, he needs to hold permits for several "receiving" locations, the prices of which are determined by supply (vulnerability, regulators) and demand (nearby would-be polluters).

the savings of a least cost scheme for control of particulate emissions in St. Louis would fall from 5/6 to 2/3 of CAC costs if uniform instruments are applied within three zones, and to 1/2 if one zone is applied. Seskin, Anderson and Reid (1983), modelling control strategies for nitrogen oxides in Chicago, find that savings of 13/14 relative to CAC fall to 1/2 if instruments have to be uniform within industries, while a scheme with completely uniform instruments would cost twice the CAC. The latter result indicates that the regulators, not surprisingly, have had an eye on the geographical dimension when designing the scheme, and thus did better than an MBI scheme which ignored it.

<u>Box 3</u>. Emission Permit Trading In Practices

Emission trading has been tried for industrial emissions to air and water in the US, and a provision similar to the offsets is in place in Germany. Expanded provisions for emission trading are proposed for the amendments to the US Clean Air Act in the US (1990).

Netting allows for internal trades within a firm in the following way; a firm can avoid the stringent emission requirements for a new source if it reduces emissions from existing sources.

Offsets address the problem that new pollution activities cannot be introduced into areas not in compliance with air quality standards. Through the offset provision, a new source may be created if it reduces emissions from another source by an even greater amount than it will emit itself.

Bubbles places an imaginary "bubble" over a factory. This allows a firm to add-up emission constraints on its various sources and thus comply with the general rather than the particular requirements.

Banking allows a firm that emits less than its legal limits to be credited, and the credits can be used later or sold to others.

Lead trading was allowed between refineries from 1982 to 1987, when they were required to reduce incrementally the lead content of gasoline.

The savings from limited opportunities to trade within bounds like these are substantial if the trade that are allowed are between sources that would otherwise abate d at vastly differing marginal costs. Hahn (1989) estimates that the savings related to netting, offsets, bubbles and lead trading have been considerable (between $1 and $12 billion), while the impact on environmental quality has been zero or insignificant.

<u>Source</u>: Hahn (1989) and Opschoor and Vos (1989), and others.

3. EFFICIENCY UNDER ALTERNATIVE ASSUMPTIONS

In this section, we discuss how the basic results in Section II are affected when we take up alternative assumptions regarding: a public revenue constraint, inability to monitor emissions and damages; uncertainty; and non-competitive market structure. As pointed out in the Introduction, these alternative assumptions may better describe the situation confronted by many developing countries.

Pigouvian Taxes Under a Public Sector Revenue Constraint

Public budgets are tight in many developing countries. Raising additional revenue through existing tax structures can often have adverse effects on resource allocation, as firms and households adapt to a distorted regime. Although tax reform can reduce these costs in many countries, such changes themselves are also costly, and the record of success is uneven (see World Bank 1988; Thirsk, forthcoming, for recent reviews). One of the attractions of pollution taxes is that they can raise revenue while improving efficiency, as firms and households are persuaded to reduce negative externalities. When there is a public sector revenue requirement, pollution taxes have a role to play in the overall tax structure. The question is at what rate they should be imposed. As is well-known from traditional optimal tax theory, taxation should be broad based in order to minimize distortions. For the polluting good, an additional "Pigouvian" term will apply.[28] Non-polluting commodities will be taxed less than if there were no net proceeds from corrective taxes, since these reduce the need for and the costs of raising revenue from distorting taxes. Consequently, taxing of commodities with negative externalities will not only reduce the efficiency losses due to externality itself (say, damage from pollution) but also the efficiency losses related to revenue generation.

[28] See Box 4 for a rigorous exposition. The result is from Sandmo (1975).

Box 4. Taxing Externalities Under a Revenue Constraint

The purpose of an optimal tax structure is to collect a given revenue requirement for the government in a way that minimizes the resource cost of taxation. Since no tax structure can tax everything, taxation has the effect of diverting resources towards untaxed goods and services (such as leisure and goods not marketed formally). The distortions created by taxation mean that the diverted resources could have been better used. For this reason, a tax structure aiming to minimize the costs of taxation will tax as many commodities as possible so that they can be taxed at low rates. Further, it will tax commodities with inelastic supply and demand relatively heavily, as for these items behavior will not be much distorted.

Sandmo (1975) examines the role of taxes that correct for externalities when taxes also serve to meet a given revenue requirement. He shows that the resulting tax structure, according to intuition, combines the features of broad, distortion minimizing taxes on all commodities, and a Pigouvian tax on the polluting good. In the case of zero cross price elasticities, the formulas are simply:

$$\frac{t_i}{P_i} = (1-\mu)\left(\frac{-1}{\epsilon_i}\right) \quad \text{and} \quad \frac{t_m}{P_m} = (1-\mu)\left(\frac{-1}{\epsilon_m}\right) + \mu\left(-n\frac{U_{m+1}}{U_m}\right)$$

where t is the tax rate, P is the producer price, m is the polluting good, i is any other good, ϵ_i and ϵ_m are compensated own-price elasticities. U_{m+1} is the marginal utility from the externality (negative) and U_m is the marginal utility from consumption of good m. As we can see, each tax formula is a weighted sum, with the weight $(1-\mu)$ given to an expression of the same form to all commodities, and the weight μ given to a Pigouvian term, which applies to the externality creating good only. The term aimed at reducing pollution equals the number n of individuals affected by the pollution, times the ratio of disutility of pollution per unit of utility from consumption of the polluting good.

Some intuition can be applied to how the corrective tax influences the overall tax structure by interpreting the weight μ, which is the ratio of the shadow price of private income to the shadow price of public income. This rate will be between zero and one when taxation is costly, since costly transfers of resources to the public sector will take place only if the shadow price of the public revenue constraints is the higher. As a special case, if the proceeds from the optimal Pigouvian tax are sufficient for public expenditure needs, μ will equal one and there will be no need for distortive taxes.

Generally, proceeds from Pigouvian taxes will make it possible to lower the rates of distortive taxes, so that pollution taxes will reduce the overall resource cost of taxation in addition to providing incentives to reduce pollution.

This complementarity between revenue and environmental objectives supports the case for charges (or auctioned permits), even though the charge and the base that maximize revenue are not equal to the efficient rate and base. No studies exist of pollution tax revenues within an optimal tax structure, but 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 permit charges would be in the some range as abatement costs. The share of charges in total control costs to the firms gets lower as the level of air quality targeted get higher, and the share is higher for emission related schemes than for the least cost (differentiated) scheme. A study of control strategies for nitrous oxides in Chicago (Seskin, Anderson and Reid, 1983) also finds charges in the same range as control costs for their three schemes.

Table 2 illustrates that the present use of charges is not of impressive significance in terms of general revenue in OECD countries (OECD, 1989). At less than a third of one percent of GNP in the Netherlands and at 0.04 percent or less of GNP in the other surveyed countries, the revenues were found to be of no importance for the general budget. The OECD study further showed that the use of charges to change behavior was extremely rare, since rates were too low and the base was usually not sufficiently responsive to individual behavior. Proceeds from pollution charges were an important mechanism for funding selective environmental expenditures in some of the countries, however, where they were earmarked for this purpose. Pollution charges may yield more or less than what is needed for environmental expenditures, so the benefits of such earmarking should be examined in the context of overall public expenditure analysis.

Table 2. Revenues of Effluent Charge Systems Compared to GNP

	Medium				Percent of GNP
	Air	Water	Waste	Noise	
	(Million ECU)				
France	19	240	n.r.	6	0.04
Germany	n.r. a/	135	n.r.	n.a b/	0.01
Italy	n.r.	n.a.	n.r.	n.r.	n.a.
Netherlands	n.a.	473	0.8	14	0.27
Switzerland	--	--	--	4	0.00
United States	n.r.	n.r.	n.a.	--	n.a.

a/ Not relevant. b/ Not available.
Source: Opschoor and Vos (1989).

Inability to Monitor Damages or Emissions: A Role for Indirect Instruments

Excluding monitoring and enforcement costs, the efficient economic policy (whether MBI or CAC) is to address the external effect directly. If emissions cause disamenities, then taxing or regulating emissions accordingly will provide the desired signals.

In reality, monitoring damages or even emissions at the source may be costly, particularly in the context of developing countries, for technological and institutional reasons. Even when monitoring is technically feasible, institutions may be too weak to ensure prudent and honest enforcement, thus rendering inefficient instruments based on emissions monitoring.

When environmental damage or emissions cannot be addressed directly because of monitoring and enforcement costs, the regulator will base his intervention on variables related to emission, such as the outputs and inputs of the polluting industry, and substitutes and complements to its outputs. We categorize these instruments as indirect instruments. An example can be indirect pollution taxes applied to fuels such as gasoline, which can be viewed as presumptive Pigouvian taxes. How will the policy choices discussed in the previous section be affected? Monitoring costs will often not affect the choice between MBIs and CAC instruments, since they will usually both be influenced in the same way.[29] With indirect instruments, the "tradeability" results apply, in that actions that reduce (increase) presumed emissions by an equal amount should receive an equal subsidy (tax). In assessing the desirability of indirect instruments, the reduced cost of the externality must be compared to the distortions they create themselves by also affecting other choices. A fuel tax, for instance, is efficient if the relationship between consumption and emissions is fixed, if non-polluting fuel use will be unaffected or is insignificant and if fuel consumption can be monitored relatively easily.[30] It will be relatively inefficient alone, however, if the fuel is used in polluting as well as non-polluting activities. Also, abatement opportunities that are not triggered by fuel economy (such as catalysts and scrubbers) can still be socially attractive options, but require instruments other than fuel taxes.

The rest of this subsection reviews the literature on how to minimize the costs of undesired incentives related to indirect instruments.

Outputs and inputs as a base. Here we present some important results on how pollution from consumption activities can be discouraged by taxing/subsidizing the polluting good and/or goods related to it in demand. The use of input taxation to reduce pollution from production activities when production is polluting is guided by the same principles.

The most important result is that if pollution is determined one-to-one by the consumption of one good, then taxing it according to marginal external costs solves the whole problem; there is no need for additional instruments since an equivalent to an emission tax has been found. Carbon taxes on fuels appear

[29]Some authors claim that to monitor compliance is more difficult if permits are tradeable. Hahn (1989) indicates that some resistance towards a specific trading program was motivated by these concerns for validation of trades.

[30]Monitoring consumption should not be read literally--for example, a fuel tax levied at one unsurpassable point in production or distribution would be sufficient. The stage at which a tax is levied sets a limit on the information content of the instrument however; input taxes may better influence input choice, but be less able to distinguish between sectors than output taxes.

to be a good example, since their external effects are independent both of source location and of combustion process. When pollution is not determined fully by an observable, taxable variable, an incentive scheme must rely on the existence of complements and substitutes, in other words, on own and cross price

Box 5. Possible Bases for Pollution Taxes

Damage Created: This base makes it possible to differentiate between polluters according to the amount of the damage caused per unit of emission. Each source equalizes marginal abatement costs to individual differentiated marginal benefits. No such taxes have yet been applied. Examples of other damage-related instruments: liability for accidents, such as oil spillage (MBI). Offsets, bubbles (MBI) and zoning (MBI/CAC) policies give some consideration to the location of the source, and thereby to the locations it pollutes (damages). Ambience permit systems are markets in damage quotas, and have been simulated but not tried in practice.

Emissions: Minimizes the costs of abatement by equalizing MCA across sources, but does not differentiate between sources according to damages. Emission charges fail to provide incentives to relocate within region. Examples: tax on emissions to air in France, water charges in Germany, waste charges in Denmark, manure taxes in Netherlands.

Inputs in and Outputs of Polluting Activities: Gives a proxy that can mimic an emission or damage tax (imperfectly). Fails to give incentives to minimize emissions (or damages) for a given level of inputs/outputs. Examples: lead in gasoline (taxed in Norway, Germany, regulated in many other countries). Fossil fuels in general are taxed in many countries, and sulphur content in fuels is regulated in many countries.

Fixed Inputs of Polluting Activities: Equipment with different emissions characteristics can provide some basis for incentives, but will fail to give incentives with respect to how carefully and frequently the equipment is used, and also fails to influence maintenance. Tax differentiation is applied according to emission characteristics of cars (Norway, Germany, Netherlands, Sweden), whereas these characteristics are regulated in many countries. Noise characteristics of aircraft are taxed in many countries. Installation of "clean" equipment/processes is subsidized or mandated in many countries.

Other Activities: Subsidizing substitutes and taxing complements are alternatives if the polluting activity is untaxable, and can also be valuable supplementary instruments. Taxation of complements (except for complementary inputs, above) is not known to be applied. As a substitute to private transport, urban mass transport is subsidized almost everywhere.

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

elasticities of demand. A quite intuitive result is that if a polluting good cannot be taxed fully, a related good should be taxed if it is a complement to, and subsidized if it is a substitute for, the polluting 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 space should be taxed. This holds unambiguously as long as demand for subway and parking space is unrelated.

When there is more than one good related to the untaxable polluting good, the answer may depend on whether the related goods are themselves substitutes or complements to each other. Wijkander (1985) illustrates some of the principles involved in the use of indirect instruments in a model where the demand for three goods (one polluting but untaxable and two clean) are closely related. If both of the related goods are complements to the externality generating good, they should normally both be taxed. Somewhat unintuitively, however, if the related goods are strongly complementary to each other, a tax would apply only to one while the other would be untaxed, or even subsidized. The case in which the two related goods are substitutes to the externality generating good is analogous; a subsidy normally applies to both unless they are strong substitutes to each other. In Wijkander's framework, it is thus possible for apparently counter-intuitive results to take place. These occur when demand relations other than the ones that have been intentionally exploited are strong, so that undesired distortions can result from the use of indirect instruments. In our motor vehicle example, if public transport and central parking space are sufficiently strong substitutes to each other, subsidizing subways and taxing parking spaces may lead to over-consumption of the former. If this problem arises, parking space should not be taxed and may even have to be subsidized.

Sandmo (1976) presents another problem in which indirect instruments are useful. A commodity is used by consumers for two purposes, only one of which has negative external effects. An example would be gasoline use, which in some cases can be said to be "innocent" when used for countryside driving but which creates pollution and congestion when used in cities. The planner, in this case, observes the demand for fuel but not how the commodity is used. A commodity tax to address the externality is itself distortionary, because it implies taxation also of the "innocent" use. The question is whether an additional instrument on a related good can reduce the costs of that distortion. Under certain conditions that relate to the regularity and stability of the demand system, Sandmo concludes that the externality generating commodity should be taxed. Further, a related good should be taxed if it is a complement to the externality generating activity and a substitute to the innocent activity, and subsidized if it is a complement to the innocent activity while a substitute to the externality generating activity. If the related good is either a complement or a substitute to both the uses, a tax (subsidy) will apply if the higher relative degree of complementarity applies to the externality-generating (innocent) good.

Balcer (1980) presents a model where some consumers create more externalities than others per unit of externality generating good consumed. Differences in demand elasticities are exploited in order to affect the behavior of "large offenders" more than the behavior of consumers in general. As a starting point, a tax on the externality generating good only (equal to the marginal damages) applies when there is no correlation between the identity of the large offenders and how complementary the related good is. In this case, we have no need for an additional instrument on the related good[31]. However, if the related good is more (less) complementary in demand for the large offenders than for the small offenders, the related good should be taxed (subsidized).

Balcer's results can be compared to those of Wijkander by again considering the transport example. Now there are large offenders (private car commuters) and small offenders (countryside drivers). The two models then largely agree, but Balcer's (and Sandmo's) framework adds that central parking

[31]This baseline is consequently identical for Sandmo (1975) and 1976), Wijkander (1985) and Balcer (1980). We may attribute it to Pigou (1920).

space should be taxed even if a fuel tax is applied to discourage driving in general. This is because taxing a commodity that is a complement to city driving makes it possible to discourage city driving without taxing "innocent" countryside driving proportionately.[32]

Only fixed inputs can be addressed. If one cannot monitor emissions or variable inputs and outputs, one can still achieve some desired response by regulating monitorable 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 for revenue purposes, based 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. As opposed to presumptive taxes for revenue collection, presumptive taxes make sense only if they affect behavior.

One can thus look at technical standards as indirect instruments under monitoring costs. The reason why such a common strategy has been heavily criticized by economists is that the regulatory approach has tended to be applied in a mandatory, uniform and thus excessively costly manner. It has also tended to be in the form of command and control whereas we have used the example of selective equipment taxes/subsidies differentiated according to presumed emissions. Often, regulations have been stricter for new sources, thus failing to minimize costs and possibly increasing the market power of incumbents.

Further, theoretical arguments as well as empirical evidence have made the point that little benefit results from "clean technology installations" if

[32]The urban transport problem includes both pollution and congestion externalities, which ideally call for both spatial and hourly variation in instruments. Congestion tolls are treated in Shah (1990). The results of Sandmo, Wijkander and Balcer fit nicely with propositions made later (Greenwald and Stiglitz, 1986), in which corrective taxes and subsidies are derived for market failure in a more general framework, utilizing the demand system in the way shown here.

they are not properly maintained or used[33]. If pollution control is to be based on such imperfect instruments as mandated technical equipment, one must keep in mind that, with the equipment they have, polluters will still pollute to the point where their marginal private benefits of doing so reach zero. It is not sufficient to lower the relative price of the cleaner technologies; one must also check that the sum of emissions from the resulting private optima will be lower (see Box 6 for an example).

Incentive incompatibility of indirect instruments. Indirect instruments alone will not enable the government to provide all the desirable incentives. In particular, indirect instruments rely on specified relationships between emissions and other variables. Consequently, actions that can change these relationships, such as some innovations, can be difficult to stimulate with indirect instruments. For instance, a fuel tax alone (or a quota on gasoline use) provides incentives to reduce emissions as long as emission economy coincides with fuel economy, but does not give incentives to actions that reduce emissions per unit of fuel consumed. A catalytic converter is an example of an abatement initiative that is not encouraged by fuel taxes, since it does not increase mileage. Devices that increase daily operating costs may even require periodic inspection to ensure appropriate maintenance and use.

It can be instructive to view the pollution control agency as the purchaser of a public good, trying to provide for the general well-being.[34] If it can monitor the depletion of the public good directly (emissions, damage), it will do so and then regulate or charge for damages. If the agency cannot monitor emissions, it will regulate or charge for related variables (proxies),

[33]Baumol and Oates (1979), Hahn (1989). The EPA tested 2000 vehicles in use between 1972 and 1976, of which 80 percent failed to meet the emission standards of their model year. Much was ascribed to deliberate cheating by car owners; half ascribed to tampering with the pollution control equipment or improper driving or fuel use (Russel 1990).

[34]Charging for the depletion of a public good amounts to the same thing. Even when permits are traded between sources, the regulator is the ultimate buyer when approving each trade. Without his participation, all would be sellers, the price would be zero and the environment would be polluted.

effectively paying for initiatives that reduce its expectations about emissions from a given source. However, using a proxy to provide incentives has inherent shortcomings. In particular, a presumptive instrument will not induce people to act in ways that will reduce emissions, unless the actions also reduce the value of the proxy.[35]

Often, monitoring more direct variables such as emissions rather than fuel consumption is not impossible but costly. Similarly, a closer match between expected emissions and actual emissions can be achieved by including more variables (vehicle characteristics in addition to fuel consumption), but at a cost of monitoring additional variables. An incentive scheme based on additional variables will always be able to induce desired behavior better or equally well. The trade-off between the gains from introducing a new variable in the incentive scheme and the increased costs in terms of monitoring and enforcement is dealt with in the literature on incentives and contracts (Maskin and Riley, 1985 provides a relevant model).

Charges and Permits Under Uncertainty

Even under perfect monitoring, the effects of environmental policies may be uncertain for a number of reasons. The benefits from abatement may be subject to events that are inherently difficult to predict. For example, the impact of air pollution can depend on the general health status of the affected population. Also, the costs of abatement depend on the flexibility of polluters, which cannot be known with certainty, and in particular not by a regulator. In developing countries, institutional development and data collection and analysis will serve to reduce the role of uncertainty over time.

[35]The relevant analogy from markets in private goods is when there is asymmetric information about product quality, and the buyer looks for characteristics of the product or the seller that indicate true quality. The efficiency costs of this information asymmetry is discussed by Akerlof (1970); he finds that, under certain conditions, there will be no market at all.

Box 6.

Incentives from Indirect Instruments: Control of Mobile Sources in the US

What many polluted cities in developing countries have in common with developed country urban areas is that motor vehicles contribute a major share of the emissions of the most troublesome pollutants. The mix is different, however; LDC cities have a higher share of heavy commercial vehicles, thus also of diesel engines. No country relies on continuous measurement of individual emissions, so all policies are related to inputs. The emission control problems also have some slightly different features; the economic lifetime of a vehicle will often be longer in a developing country, thus rendering policies that solely regulate the characteristics of new cars less effective in the medium term. Also, if institutional capacity is less developed, there is probably less scope for inspection programs to induce maintenance that keep emissions down.

In the US, vehicle emissions of such substances as lead, carbon monoxide, nitrogen oxides and hydrocarbons have been targeted by the provisions in the Clean Air Act with impressive results. Measured as emitted quantities per mile from new vehicles, hydrocarbons are down by 95 percent, carbon monoxide by 96 percent, nitrous oxides by 72 percent and lead by 95 percent.

The achievements have been accomplished by increasingly strict tailpipe standards for new vehicles, with which auto manufacturers have had to comply as well as by restricting lead in fuels. Thus, the major control instrument has been source specific constraints applied to equipment, as opposed to two other alternatives. Cars could have been taxed presumptively according to emission characteristics, and instruments addressing variable inputs such as fuels and road use could have been introduced. There are some apparent efficiency problems related to the chosen equipment CAC strategy, some of which are partly addressed by supplementary instruments such as:

Incentives to maintain low emissions. Emission characteristics may deteriorate over time due to deliberate tampering or negligence. For areas not in compliance with federal air quality standards, inspection and maintenance programs are mandatory, but since testing is preannounced the reading is an inaccurate and biased indicator (Stedman et al 1990).

Regulation addresses ownership, not use. By addressing fixed equipment only, no incentives are given to use the car less, and low users are not given options to invest less in abatement equipment. The problem is only partly addressed by supplementary instruments such as fuel taxes. Neither urban road user charges nor taxation based on odometer reading is used.

Lack of geographical variation. Pollution levels are not problematic in the countryside, and more problematic in some cities than in others. Stricter tailpipe standards are now recommended for the most polluted cities, inspection programs are mandated only in non-compliance areas and fuel taxes vary between states (while low everywhere compared to Europe). Road charges and subsidies to public transport are probably indispensable if one wants stronger geographical variation, and this would allow for lower overall costs.

How are the recommendations about the choice of instruments affected by uncertainty? One result is that the equivalence of price based versus quantity based instruments may no longer hold. Another result is that in an uncertain environment, flexible instruments are better. Also, liability rules may be an attractive option.

The nature of the uncertainty. A widely cited advantage with quantity instruments is that emission standards are met with certainty regardless of uncertain costs. While this is true, price instruments ensure that emission reductions are acquired at a certain cost. The conditions under which one instrument type is favored over the other has been studied by Weitzmann (1974).[36]

The planner has to choose between price or quantity controls, based on ex ante probabilit distributions of benefit and cost functions while minimizing the ex post efficiency costs. An important result is that when the marginal costs of abatement are known, uncertainty about tne benefits does not favor one instrument over the other. Firms abate only on the basis of their costs and of the policy instrument, which are both known. So, even if the benefits deviate from expected levels, the abatement level and the efficiency losses will be exactly the same for the price and the quantity instrument.

When abatement costs are uncertain, producers are assumed to have information which the planner does not have, and their actions may therefore differ from those the planner had expected. The result is a distinction in efficiency between intervention via prices and quantities determined by the shape of the benefit and cost functions (Weitzmann 1974):

> When marginal costs are nearly flat (while the marginal benefits are steep)[37], the smallest miscalculation or change results in either much more or much less than the desired

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[36]This distinction does not relate to whether policies should be MBI or CAC, as long as quotas can be traded. The issue discussed here is that under uncertainty, the equivalence between a quantity instrument and a price instrument may not hold.

[37]Our remark.

> quantity...Using a price control mode in such situations could have detrimental consequences... the centre cannot afford being even slightly off the mark.[38]

In other words, the quantity instrument, which can guarantee an emission level, is better if it is costly to realize unexpected emission loads. Similarly, the price instrument is better if deviations in emissions are less costly than unexpected marginal abatement cost, since the price instrument fixes the marginal abatement costs. As an example, consider a case in which a collective treatment plant has zero variable costs and fixed capacity and in which stressing the capacity constraint has detrimental consequences. If the marginal abatement costs for each source are flat, one would want total discharges to be within the available treatment capacity. A quantity instrument such as tradeable permits would serve that purpose while a price instrument would risk costly under- or overutilization. A steep benefit curve similar to this case is illustrated in Box Figure 7b.

The relevance of uncertainty in an empirical example was studied by Kolstad (1986), who evaluated policies to control sulphur emissions from power plants. Uncertainty about future electricity demand resulted in uncertainty about abatement costs. He found that if marginal benefits were constant, a price instrument would be slightly preferable, but that a slight slope would be enough to make permits the more desirable option. Lyon (1989) argues that tradeable permits are particularly attractive from a developing country point of view, mostly because they provide certainty about ambience quality in a dynamic context, but also because they allow implicit property rights to be changed gradually. One could, however, interpret developing countries' caution with environmental policies in a way that would favor price instruments. If marginal benefits are seen as fairly flat while the costs of abatement could be steep and

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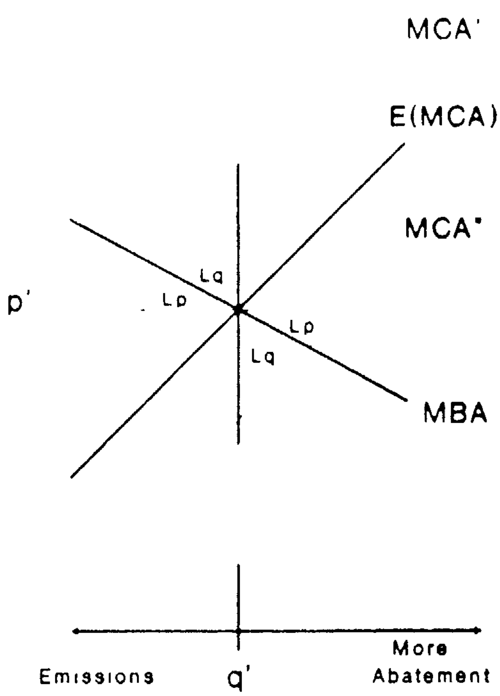
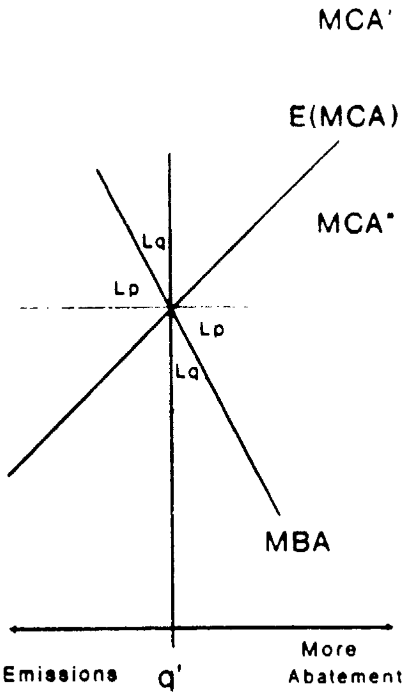
[38]Baumol and Oates show that prices minimize ex post efficiency losses if the marginal cost function is steeper than the marginal benefit function, while tradeable permits are better if the benefit function is steeper. They use linear marginal cost and benefit functions, with the stochastic term shifting costs in a parallel fashion.

are uncertain (Box Figure 7a), price instruments could ensure that no surprisingly costly controls are implemented.

Box 7: **Prices Versus Quantities Under Uncertainties in Abatement Costs**



Box Figure 7a



Box Figure 7b

Marginal abatement costs are uncertain; MCA' and MCA" illustrates likely outcomes, E(MCA) expected outcome. Since marginal abatement costs will differ from expectations, there will be a welfare loss associated with abatement that is not optimal, evaluated ex post.

In each figure, an area like L_p illustrates expected welfare loss with a price instrument p', and L_q illustrates expected welfare loss with a quantity instrument q'. In figure 7a, the marginal benefits of abatement are flat relative to costs, and a price instrument will minimize welfare losses. In Figure 7b, marginal benefits are steeper and a quantity instrument minimizes welfare losses.

If several instruments can be used to force realized allocations to approximate (ex post) optimal ones as closely as possible, a combination of instruments may be better than only a quota or a price. Along these lines, 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 to additional abatement) at a (low) price. "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." Thus a permit alone can be interpreted as a special case under this scheme, where the subsidy is zero and the penalty is prohibitive. What this scheme adds is an opportunity for emissions to be higher if the costs of abatement are very high (so high that the planner would have distributed more permits, had he known), and it provides incentives for a cleaner ambience, should abatement costs be low. If, as Roberts and Spence assume, the permits are tradeable, the costs of abatement will be equalized so the resulting ambience standard will be achieved at least cost.[39]

Instrument flexibility. In the above problem, the planner e .blished the rules and the producers reacted to them. What if the planner can to some extent adjust his use of instruments when information is revealed? The above results may change if some instruments are more easily adjusted than others. Bawa (1988) suggests a mixed policy under the assumption that a regulatory instrument (command and control) can be implemented with greater speed and flexibility than a charge (or a tradeable permit).

The structure of the problem as follows: Assume that effluent charges can be changed only sluggishly, but that stochastic changes (for example, in weather conditions) make the ambience quality resulting from a steady flow of emissions worse in some periods than others, the periods being too short for the effluent charge to be adjusted accordingly. If a command and control instrument can be used directly on the worst days (factories closed down indiscriminately or randomly under "smog alert"[40]), the increased abatement is achieved though it

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[39]Beavis and Walker (1983) analyzes a problem in which individual emissions are stochastic, and in which an ambience quality constraint is to be satisfied with a prespecified probability. The scheme involves two charges, one for the mean of emissions and one for the variability of emissions.

[40]Plourde and Yeung (1989).

may not be efficiently distributed. A constant charge alone will result in high abatement costs, since there will be excessive abatement all days when the absorptive capacity of the environment is high. The lower the charge, however, the more often abatement will have to be implemented by command and control measures, which means that, during those days, abatement will be inefficiently distributed among firms. A mixed policy consisting of a charge that maintains the ambience standard on most days supplemented by command and control to provide additional abatement on the rest of the days is suggested. This would trade off the benefits of the efficient inter-firm distribution of abatement through charges and the costs of abating excessively on windy days. Sebastian (1989) reports that industry and regulatory authorities in Mexico city have signed an agreement of pollution alert and shutdown when ambience concentrations reach critical thresholds. Over the last few years, there has been two to three shutdowns.

Liability to victims as an instrument. Under asymmetric information about actions taken to avoid damage, the polluter's liability for actual damage can be useful under certain conditions. Bohm and Russel (1986) writes: "If monitoring of actions to avoid causing damage is expensive...but the source of actual discharges or spills could be identified ex post, a liability rule might usefully substitute for a regulator rule".

Liability under these circumstances has strong parallels with the Coasean proposition that negotiations without intervention are efficient. However, negotiation (under the threat of litigation) will usually take place ex post in the case of liability, so there is not much concern about the potential victims unless they are well protected legally.[41]

If there are no problems either with assessing responsibility for damage or with representating the victims' interests, it seems that both liability and prior regulation can do the job of providing incentives for prevention.

[41] Also, the Coasean "neutrality" of initial distribution of rights may not hold under asymmetric information, so that a universal obligation not to inflict damage can be necessary for efficiency.

Intervening with a set of instruments defined in advance provides advantages in terms of preparedness[42] and standardization, and ideally represents the interest of all victims with no coordination problems (though with certain uniformity constraints that are inherent in any regulatory procedure). Liability allows for more flexible case by case damage assessment but may be costlier and may face serious problems in representing all victims interests.

Incidents such as the Bhopal catastrophe and the Prince William's Sound oil spillage (with sizeable damage awards and losses of reputation for the firms involved) probably make firms aware of their potential liability, and thus induce them to the additional care. The incentives resulting from potential liability may be limited by the following, however: low likelihood of detection, costs of litigation and representation of victims, as well as by the quality of the judicial process. In the end, the entity found liable has to be solvent for the penalty to be real. Ringleb et. al finds a tendency that small, independent firms take over the business areas with greatest risks in the U.S., where liability is generally unlimited. This trend could indicte that less wealth is backing the potential liabilities, and thus less powerful incentives.[43] In addition to these considerations, Bohm and Russel note that the liability instrument may provide incentives for people not to protect themselves against pollution, since the price paid by the polluter is actually received by the victims. Kolstad et al. (1990) add that uncertainty about liability assessment gives a rationale for supplementing ex post liability with regulatory standards.

Case by case solutions such as liability suits and negotiations between polluters and victims are complementary to regulations. Farrel (1987) thus proposes that a regulatory framework should solve problems that cannot effectively be solved by complementary case by case approaches. This would

[42]No doubt, this preparedness can assist in assessment of responsibility for damage, as when it results in a monitoring capacity.

[43]An example could be that Shell has announced to pull out of oil transport in U.S. waters (Financial Times, June 15, 1990).

indicate that intervention (taxes or permits) is less necessary when culprits are few and easily identifiable (major oil spills) than when the likelihood of being held responsible by victims is low (as with many air pollutants). The complementarity of the two approaches is discussed at length in Posner (1986, Chapter 13)..."between the common law system of privately enforced rights and the administrative system of direct public control...should depend upon their strengths and weaknesses in particular contexts".

Noncompetitive Market Structure

The basic rules about policy intervention as outlined here are derived from the assumption that markets are competitive. But in many cases, such an assumption is untenable. In many developing countries, markets may be small, entry barriers, tariffs and transportation costs high, and access to credit, technology and law enforcement limited.

How do the recommendations regarding policy intervention change when the polluting firm is also a monopoly (such as a utility) and uses its market power to supply less than optimal output? In this case, there are two sources of market failure--pollution externalities and market power. Two instruments (for example, a subsidy on output to correct for market power and a tax on emissions to correct for external effects) are sufficient to achieve efficient resource use. The rate of tax on emissions would then be guided by the same rule as that for competitive firms, since the firm would set their prices equal to marginal private costs.

If a tax on emissions is not feasible because of monitoring costs, can one remaining instrument, a tax or subsidy on output, address both sources of market failure? Buchanan (1969) proposed "the dismantling of the Pigouvian tradition", based on the argument that since the monopoly's output is less than optimal already, a Pigouvian tax on output is likely to aggravate this problem. Baumol (1972) dismissed Buchanan's point as insignificant, noting that most significant pollution problems are affected by "large numbers" of firms. This claim pays insufficient attention to the fact that it is the number of firms within each industry, rather than behind each pollutant that matters (Burrows, 1981). Analyzing more general pollution control instruments, Burrows points out that the risks that pollution taxes will increase welfare losses rise as the importance output reduction in pollution abatement rises; equivalently the risks get less as the importance of process switching (or end of pipe purification) rises.

Thus, the point that a monopoly may in fact already have internalized an optimal Pigouvian tax through its exertion of market power is a theoretical possibility. The problem of calculating a "second best fee" on the grounds that "the environmental agency...will typically have neither the authority nor the inclination to offer subsidies to monopolists... it is empowered only to tax emissions" (Baumol and Oates, 1988) then weighs these needs against each other when calculating the effluent charge. The result is a sum of a Pigouvian tax and a subsidy to output. This sum collapses to the familiar Pigouvian tax if the industry is competitive, and it is zero, as Buchanan suggests, in the special case where the two cancel each other out. The derivation of a second best fee for oligopoly would depend on the behavioral assumptions about the firms, but would essentially incorporate the same trade-off between the concerns of market power and excessive pollution.

Utilities are usually prime examples of monopolies in developed countries, but they are often subject to controls both on pricing and on emissions. In developing countries, utilities are often public and loss-making, which warrants some additional study of behavior (for example, profit maximization, and even cost minimization, may be unrealistic) before an incentive scheme is designed.

The problem of imperfect competition is more troublesome 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 efficient, even if the number of permits available is optimal. Since permit markets will often be fragmented, interdependent and thin, this may provide an additional argument for using price instruments.[44]

Another problem is that pollution abatement policies may themselves influence the market structure. A number of authors study how the theoretical recommendations of abatement policies can affect the number of firms (Deewes 1983, Kohn 1985, 1988, Mestelmann 1988, Spulber, 1985). This literature broadens the usual partial equilibrium, short-run perspective by studying how the effects on inframarginal profits affect entry, exit and capacity investments and by allowing for economies or diseconomies in abatement. One result is that different policies may affect the number of firms, and thereby the extent of market power. This result is intuitive, but contrasts the neutrality of nonmarginal rewards derived in short term models.

If a firm's exit from the market would be triggered by a reduction in its profits, the number of firms will be reduced by any policies making polluters pay.[45] Quotas and standards, similarly, could provide for collusion among existing firms, if they raise the costs of entry. Assuming competitive behavior, Spulber (1985) shows that an optimal effluent charge (or number of tradeable permits) will yield the efficient number of firms and efficient output even if there are economies or diseconomies of scale in abatement.

There are many claims that industries in developed countries have become more concentrated as a result of environmental control policies (paper and pulp, copper smelting). It is not clear, however, whether this is a necessary result or whether the excessive focus on mandated equipment has allowed for increased

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[44]It is here assumed that the polluters suppose they cannot influence the effluence charge. If polluters behave strategically to manipulate the charge, problems similar to those in permit markets will emerge.

[45]The polluter pays principle (PPP), as defined by the OECD (1975, 1989), has some desirable and some undesirable implications for efficiency. It has been a guideline within the OECD since 1972.

concentration.[46] However, there are other examples such as fossil-fueled power generation in the US, indicating that pollution control policies have eroded some of the possibilities for economies of scale, thus giving a boost to small plants.[47] In developing countries, small firms in the informal sector are often major polluters. While restructuring and concentration could lower the costs of monitoring and enforcement, this would often be at the unacceptable cost of closing down lean and flexible production capacity. A suitable policy should take account of the effects of the control approach on the plant population, in order not to spur major restructuring (and possibly market power) unless it is necessary. Flexible indirect instruments may be a way to curb emissions from small firms, while avoiding to force them under ground or out of business.[48]

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[46]As noted earlier, abatement activities that rely on equipment and fixed installations may justifiably be preferred to other, equally cheap abatement options if the are less costly to monitor.

[47]Gollop and Roberts (1983) report find econometric evidence.

[48]The size of firms could yield economies of diseconomies of scale in production, abatement and monitoring. The latter has not been dealt with in theoretical literature.

4. DISTRIBUTIVE EFFECTS: WELFARE AND POLITICAL ECONOMY

We will here discuss two rationales for paying attention to the distributive effects of environmental policy. Up to this point, we have concentrated on the efficiency aspect of policy instruments, which is a good criterion if one is interested in minimizing total costs. However, minimizing total costs need not be a dominant criterion if mechanisms for distributing costs and benefits are not well developed. One rationale for looking at distributive effects is that an increase in the income for certain groups (for example, the poor) may be valued more highly in social welfare terms than that of other groups. Another is that the government should know who benefits and who loses so that it can judge whether a particular reform will have sufficient political support to be adopted and implemented.[49]

Environmental Policies and the Poor

What impact do alternative policies to control pollution have on the poor? Does government need to consider compensatory mechanisms for protecting the poor?

The distribution of the benefits of pollution control is an empirical issue. 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), since they tend to live in poor health and sanitary conditions in polluted urban areas and cannot afford to protect themselves or move. U.S. studies[50] have shown that air pollution is worse in cities that have a large poor population. Within cities, air pollution is worse in the areas where poor live. It has also been found that air quality improvements have been more significant in areas with many poor, so that in quantity terms the air quality improvements

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[49]The perspective of this paper 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), Hahn (1989) and Zechhauser (1981) for applications to environmental policies.

[50]These studies are reviewed in Christainsen and Tietenberg (1985).

appear to have benefitted the poor more than the rich (Asch and Seneca, 1978). While such observations may be important, theoretical arguments and some empirical evidence indicate that the willingness to pay for environmental improvement among wealthier individuals may be higher than that among the poor. Such differences in willingness to pay could make the wealthy the principal beneficiaries (Christainsen and Tietenberg, 1985).

In most of the studies comparing the incidence of alternative policy instruments, the distribution of benefits is generally assumed to be uniform. An exemption is Harrison (1975) who notes that the policies to control air pollution from motor vehicles in the U.S. have affected the rural poor badly both on the benefit side and on the cost side, since their car ownership rates (and thus control costs) are necessarily high while the environmental benefits in their areas are modest. Harrison concludes that the costs of controlling vehicle air pollution have been progressively distributed within cities but have been regressive overall, since the poor in rural areas have suffered from higher costs of private transport without having alternatives. Proposals that would address this incidence problem by introducing stricter emission requirements for "urban" than for "rural" vehicles are included in the proposals for the 1990 Clean Air Act Amendments, requiring "cleaner" cars and fuels to be sold in the most polluted cities. Such differentiation is desired for efficiency reasons also, if damages per unit of emissions are lower in less polluted areas.

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, one needs to analyze the elasticities of demand and supply in production and consumption as well as 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 who do not use public transport. A diesel price hike may affect commuters and rural communities that depend on commercial or public transport. Regulatory intervention can also have distributive effects because it affects the cost of doing business, which can be shifted forward to prices or backwards to labor and capital. The poor may be more vulnerable to selective price increases, and may be more at risk of unemployment if an industry becomes uncompetitive.[51]

In industries for which environmental regulations are very costly, changes in costs and practices may affect incidence. For instance, if labor is a substitute for polluting inputs, abatement policies can lead to increased labor-intensity in production, and may thus result in increased employment and/or increased remuneration of labor. In a simple theoretical general equilibrium framework, Forster (1983) analyses the effect of sector specific abatement requirements, modelled as an increase in unit costs in that industry. With two mobile factors in fixed supply and flexible factor prices, the factor most intensively used in the affected sector will lose while the other factor will receive increased remuneration. Alternative assumptions, such as the introduction of price/wage rigidities (and thereby possible unemployment) or immobile factors, can, of course, give different 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 UK by 20 percent would raise eight billion pounds in the short run and three billion pounds in the long run, the decline representing a decline in the rate necessary to sustain lower consumption. The tax would be highly regressive, reducing the welfare of the poorest with up to 2.7 percent compared to only 0.4 percent for the richest decile.[52] They do find, naturally, that if all the proceeds were redistributed to the poor the scheme could end up being progressive.

Since the poor are likely to have a greater propensity to spend their income, price increases in general will tend to have a regressive impact.[53]

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[51]Yu and Ingene (1982) and Yoke (1979).

[52]A rough approximation (our calculation) using Roy's identity and a money measure of utility.

[53]Gianessi, Peskin and Wolff, 1979, Dorfman, 1975.

Over and above this, Yan (1975) found no pattern of regressivity or progressivity due to the specific prices that increased as a result of environmental policies. Also, in the area of water pollution control, the effect through prices has been found to be regressive because of differences in propensity to consume. Treatment plants, on the other hand, are partly financed through charges and through local and federal taxes. The impact of these charges appear to have been progressive in some cases and regressive in others.

The need to protect the poor. Often, particular measures to protect the poor from the net effects of environmental policies will not be necessary. For example, where the distribution of benefits is neutral or progressive and the burden of costs falls mainly on the rich, full charges for damages will be efficient and will have a positive equity impact. A theoretical analysis within the context of an optimal tax scheme is given in Sandmo (1976). This model allows individuals to differ with respect to productivity and thus income. The redistributive objective modifies tax rates in a way well known in many-person optimal tax rules. The revenue collection terms in the formulas given in Box 4 are adjusted downwards for commodities predominantly consumed by the poor and upwards for those consumed mostly by the rich. The adjustment of the Pigouvian term depends on an additional factor; the income group's rate of substitution between the externality itself and the externality creating good.

Thus, if the low (high) income groups suffer most from the damage of the externality per unit of utility from the good itself, the Pigouvian term will be adjusted upwards (downwards). In other words, the Pigouvian tax for the externality-generating good will be adjusted upward by the redistributive weights if the poor are relatively more damaged by the externality, but only if they are not also particularly dependent on the consumption of that good. Conversely, a polluting activity should be curbed less if its benefits accrue mostly to the poor and its negative externalities mostly to the rich. It should be clear from this that equity concerns in themselves do not imply stronger or weaker environmental protection measures, since parame rs that are theoretically relevant may go either way and need to be assessed empirically.

__Political Economy and Implementation__

If some policies are so much better than others (for instance, MBI instruments rather than CAC, direct rather than indirect), why are they not applied more in practice? Recent research has indicated that policy outcomes are influenced by who gains and who bears the burden of different strategies.[54] 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) 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...The 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 who, for any given level of abatement effort, strongly prefer not to pay for the remaining emissions. The agency, on the other hand, is likely to settle for any solution that is consistent with its ambience quality goals. Such an outcome would be politically expedient but economically inefficient for the reasons outlined earlier. Those who pay the additional costs of inefficient intervention are citizens at large, often badly organized compared to the industry in

[54] See Hahn (1989) for a brief review and interpretation, see also Baumol and Oates (1979) and (1988), Dewees (1983), Buchanan and Tullock (1975).

question. In addition to the inefficiency problems already mentioned, real world CAC policies tend to be selective and thus very prone to rent seeking behavior.[55]

Empirical evidence on incidence and its role in implementation is scant. Few doubt that industries influence their regulatory environment and indeed, under CAC, it is probably conducive to efficiency that they do, as long as the regulatory agency is well equipped. The more prominent challenge for a regulatory agency is probably to make sure that both the potential competition of the affected industry and citizens in general are well represented.

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[55] Zeckhauser (1981) advises that: (i) effective policy takes account of both the net benefits a policy offers and the probability that the policy will be adopted; (ii) the probability that the policy is adopted depends on the distribution of benefits and costs it confers on organized and unorganized constituencies; and (iii) simple analytic models provide a framework that not only should prove helpful prescriptively but also helps explain some observed aspects of the policy formulation process that might otherwise appear puzzling. Other authors allow policies to result from maximizing behavior of different interest groups, including the regulating and enforcing agency (Lee, 1984, Linder and McBride, 1984) and procontrol citizen groups (Downing 1981).

5. SUMMARY AND AN AGENDA FOR DEVELOPING COUNTRIES

The case for government intervention to address pollution problems is reasonably well established in the literature; many pollution problems involve such large numbers of potentially affected individuals that the absence of intervention is likely to be costly and result in too much pollution. The policy objective is to induce economic agents to internalize the pollution externality in their behavior. Governments must choose from a range of policy instruments by comparing broadly defined benefits and costs. In this paper we have reviewed the theoretical and empirical literature comparing these instruments. The main issue we want to discuss in this last section is which of these general recommendations are of particular relevance to developing countries. Which policy instruments are more appropriate (in other words, efficient, implementable and equitable) given the constraints that developing country governments confront? What research must be done in order to provide better answers to the questions we have raised?

Choosing Policy Instruments in Developing Countries

Our goal has been to show how problem specific conditions should shape control policies, and that high and unnecessary costs are easily incurred if one does not take into account conditions such as: (i) institutional and technical capacity; ii) revenue constraints; (iii) uncertainty; (iv) market structure; and (v) distributive implications.

The earlier sections outlined some broad guidelines based on a review of the literature. Some of the more important conclusions are as follows:

-- Market based incentives (MBIs) minimize the social costs of achieving a given environmental improvement and thus dominate command and control (CAC) approaches.

-- Among MBIs, price based approaches are generally equivalent to marketable permits in terms of efficiency, when administrative costs, uncertainty and other complicating factors, are ignored. It is not possible to conclude in general whether administrative costs are more onerous with one regime or the other.

-- Among price based MBIs, taxes and subsidies can be equally efficient in the short run. Such schemes should target damage or emissions directly, if possible, and the rate should be set so that the social cost of the damage is internalized by the polluter. For an incentive scheme to be efficient in the longer term, the arguments for taxing pollution rather than subsidizing abatement are strong.

-- Indirect instruments, such as taxes and subsidies on inputs and outputs, may be efficient second best choices if targeting damages or emissions directly is not possible due to the costs of monitoring and enforcement.

-- When public funds are scarce, taxes, charges and permits sold at market prices have the additional advantage of generating revenue.

-- If there is uncertainty about abatement costs, price instruments (as opposed to permits) can ensure that one does not embark on policies that result in surprisingly high costs for only moderate benefits. In contrast to permits, however, the price instruments do result in uncertainty about resulting emissions.

Applying these broad guidelines in practice requires taking into account the specific characteristics of the country as well as of the pollution problem itself.

Developing country characteristics. Although the pollution problems and the economic conditions of individual developing countries are diverse, it is nonetheless useful to review how general considerations for this group could affect the choice of policy instrument. One important characteristic is that pollution abatement is likely to be relatively costly in developing as compared to developed countries. Private businesses are confronted with constraints that can make it more costly to reduce emissions no matter which policy instruments are used. They often face a high cost of capital, partly due to the inefficient state of the formal financial markets (see World Bank 1989). Moreover, modern technology and relevant expertise may be scarce in developing countries. Some countries are saddled with an outdated production technology built when pollution was not deemed to be such an important concern. Limited technological capacity will also constrain the ability of public authorities to monitor and enforce, which increases the dead weight losses related to any intervention scheme. On the other hand, only moderate and inexpensive abatement initiatives may be required, if the pressure on the environment is low at early stages of development.

Another concern is based on institutional capacity. The emissions of many pollutants can only be imperfectly monitored, and the fact that monitoring is to result in monetary implications for the polluter does not make the task easier. In the U.S., for example, the Environmental Protection Agency has 14,000 employees (federal level only), and even so most sources are not continuously monitored.[*] The monitoring problem is likely to be worse for regulatory agencies in developing countries since they are often badly funded and have less access to technology and trained manpower. The ability to monitor in a cost-effective way is important for the choice of instruments, because many of the popular theoretical recommendations are predicated on an ability to discern emissions from each individual polluter. A further dimension of institutional capacity is the regulatory agency's ability to design and administer new schemes, since behavior will change only if a threat to penalize noncompliance is seen as credible. Even in developed countries, sophisticated schemes, such as permit trading, have run foul of implementation issues (Hahn 1990).

Finally, distributive implications are important. The political economy of policy reform can give very costly outcomes in developing countries, where privileged groups are often stronger and do not have to contend with well entrenched institutional processes. Mechanisms for compensating transfers are often not well-developed, and any reform must, therefore, also take account of the impact on the most vulnerable groups in society.

Implications for policy reform. These considerations might affect the broad guidelines regarding the ranking of policy instruments. They probably strengthen considerably the case for price based versus quantity based interventions, particularly if the instruments are based only indirectly on damages or emissions. In an uncertain world, price based instruments provide greater certainty regarding abatement costs. Such instruments are superior when

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[*]Clifford Russel (1990) notes that the EPA largely trusts corporations in compliance and self-reporting, even though experience with motor vehicles has shown that active tampering (not only inadequate operation and maintenance) is prevalent.

there is concern that underestimating the costs would yield controls that are too strict and environmental quality that is "too high". Such concerns arguably persist in many developing countries, and then price instruments can be particularly helpful. Second, even though quantity based interventions that incorporate aspects of MBIs (such as tradeable permits) have many attractive attributes, they will in most cases imply the setting up of new administrative systems. Many countries already have ways of charging for or taxing relevant commodities, and the administrative capacity to manipulate domestic relative prices is often well established. What price based interventions and permits have in common is that they can generate revenue. However, the potential contribution of revenues from pollution control instruments, like taxes or prices, is small in relation to the overall needs of the treasury.

The costs of monitoring emissions or damages and of enforcing instruments related to them can be high, particularly in LDCs, for technological and institutional reasons. Then, indirect taxes and charges (taxes/subsidies to marketed inputs and outputs) are desirable because they depend less on vulnerable and costly monitoring and enforcement functions. However, these instruments also imply additional costs because they can only imperfectly mimic monitored emissions and damages. Good indirect instruments affect the profitability of abatement options without affecting other choices. The balance between ideal incentives and the costs of implementing them depends on the links among the demands of various commodities (in other words, the cross price elasticities of demand), on the degree of technical substitutability among various inputs and on how emissions are affected by different actions. The choice of which commodities to tax and at what rates should also be sensitive to the probable incidence. These issues should be the subject of future research.

These considerations do not mean that instruments such as tradeable permits should not be attempted, but that less sophisticated instruments should be considered wherever they have the potential to do much of the job in an implementable, low cost way. Then, monitoring and enforcement capacity can be developed and prioritized for remaining problem sectors/pollutants. Also, schemes that encourage self-compliance, such as deposit refund systems, should be considered. Many developed countries are just starting to investigate these possibilities.

Research Agenda

Given the set of conceptual and empirical studies we have reviewed, we think that future research efforts should include the following areas.

Case studies on the source and severity of problem. What are the main pollution problems in typical developing countries and what policies are currently in place to address them? What other public policies have affected the magnitudes of these problems, and how? The benefits of pollution control, the costs of abatement, the constraints on available instruments all have significant problem and site specific characteristics. The main objective should be to gain insights into the constraints on and aspects of instrument choice that may be different from those in developed countries.

Empirical estimation of the costs of pollution control. The costs of pollution control depend on (i) the flexibility of consumers to substitute to less polluting consumption patterns; (ii) the flexibility of producers to substitute to less polluting inputs/processes; and (iii) the extent to which policy instruments can be found that can stimulate such change. Commodity specific pollution coefficients will make it possible to estimate the costs of internalizing pollution externalities through the demand system. Demand system estimation provides inputs to analyze of overall costs of pollution control, as well as the incidence and revenue implications. Estimating substitution possibilities on the production side, including the related response in emissions, is also necessary. Both engineering and econometric approaches should be used in this effort. Applying the taxes on imperfect emission proxies, such as input use, allows for tests on the costs of monitoring and enforcement constraints.

Conceptual and empirical work on instrument choice. The costs of monitoring and enforcement, apart from considerations of political economy, deserve a more explicit treatment in order for the practical challenges of instrument choice to be understood. The problem of providing incentives under information constraints, particularly when information about damages is asymmetrically distributed, is not sufficiently explored in environmental applications. Besides conceptual work, empirical work will be needed on monitoring/enforcement costs. These need to be weighed against the costs of indirect instruments, which provide an alternative that fails to offer some desired incentives but in return yields lower costs of monitoring/enforcement costs.

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