Designing Economic Instruments and Participatory Institutions for Environmental Management in India

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Abstract

This paper examines the possibility of using economic instruments, especially pollution taxes and bargaining approaches, as a means to encourage or improve people's participation in environmental management in India. It provides an intuitive description of methods for designing economic instruments and bargaining approaches. A case study describes the estimation of pollution taxes for controlling air pollution in thermal power generation in India. Another case study examining some bargaining methods that are already in force in India shows their usefulness in controlling industrial pollution.

Key Words: Pollution tax, Bargaining, Collective action, Transaction costs, Decentralized solutions, India

Designing Economic Instruments and Participatory Institutions for Environmental Management in India

M.N. Murty

1. Introduction

Environmental resources such as air and water have some natural regenerative capacity. They can therefore accept a certain amount of pollution loads from anthropogenic activities without any damage. But limits to the natural regenerative capacity of air and water impose a constraint on both the demand and supply of waste disposal services. Therefore, while industry and households demand waste disposal services, if this demand exceeds the supply constraints imposed by the regenerative capacity of the natural resource, it will lead to the degradation in the environment. Given the 'public goods' nature of waste disposal services[1], there is no market for this service, the tendency being for the polluter to take it as a free service. As a result, the demand for waste disposal services may exceed the natural supply of such services. The challenge then is to come up with instruments and institutions to bring the demand for waste disposal services down to their natural levels of supply.

This paper examines the possibilities of using economic instruments, especially pollution taxes and bargaining approaches, as means to encourage people's participation in pollution control. Section 2 provides a brief and somewhat non-technical account of the alternative instruments and institutions for pollution abatement. Sections 3 and 4 respectively describe available methods for designing pollution taxes and participatory institutions to control industrial pollution in India. Section 5 gives the conclusions and policy implications.

2. Alternative Instruments and Institutions for Pollution Abatement

There are three alternative institutions for the control of environmental pollution: (a) market; (b) government; and (c) community or associations of people. But a practical policy may have to involve all these institutions[2]. The general assumption is that market forces alone fail to control environmental pollution. Although traditional thinking saw the government as an alternative institution to manage the environment, community action or people's participation is now gaining prominence as an alternative to governmental agencies for the management of environmental resources[3].

2.1 Market, Government and Instruments for Pollution Control

Non-market policy instruments include command-and-controls (CAC) while market-based instruments consist of pollution taxes (Pigou, 1920) and marketable pollution permits (Dales, 1968). These are often referred to as economic instruments. The choice between these instruments

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1 Since waste disposal service has the public good characteristics, it cannot be disposed by charging a price for it.

2 See Murty *et al.* (1999) and World Bank (1999) for details.

3 This alternative is now becoming attractive because of high monitoring and enforcing costs to the Pollution Control Boards and other governmental agencies and due to corruption in government, especially in many developing countries.

depends both on their efficacy in achieving the target level of emissions as well as on the relative size of welfare losses they produce (Baumol & Oates, 1988). The government can use either non-market policy instruments, or market-based or economic instruments, or a combination of the two as its policy to control pollution.

2.1.1 Command and Controls (CAC)

The CAC instruments are in the form of fines, penalties and threats of legal action for closure of factories and the possible imprisonment of the owners. The state can use them either to facilitate the use of specific technologies for purposes of environment management or to realize specific environmental standards. It is known that the cost of imposing and implementing compliance are generally higher when the state resorts to CAC instruments rather than economic instruments. Furthermore, under CAC instruments, there can be no incentives for firms to innovate or invest in more efficient pollution control technologies or in cleaner process technologies.

2.1.2 Economic Instruments

We can divide economic instruments into three categories: price-based instruments, quantity-based instruments and hybrid instruments. These instruments are also known as market based instruments in the literature. Together with the supply-demand forces of the market, they achieve efficiency in the presence of environmental externalities like air and water pollution.

2.1.2.1 Price-based Instruments

Pigou (1920) was the first to suggest price-based instruments in the form of taxes and subsidies, when it comes to production and consumption, in order to deal with detrimental and beneficial environmental externalities. Examples were pollution taxes on a polluting commodity either through its production (that is, paper, leather, electricity, etc.) or consumption (that is, as cigarettes, packed foods, etc.) or on a polluting input (such as fuel inputs, chemicals, etc.). It could be a tax on either the polluting output or the pollution load. The economic instruments could be subsidies on the commodities the production of which generates environmental benefits (such as a neighbor's rose garden which gives off a free benefit in the form of beauty, or forest conservation which checks soil erosion downstream of a watershed, etc.). We could call the pollution tax or Pigouvian tax a corrective instrument to realize a socially optimal level of economic activity in the context of pollution generation.

Pollution tax is considered the price the polluter has to pay for using waste disposal services from environmental media. Since there is no market for waste disposal services, this price cannot be determined in the market. In other words, the supply and demand schedules for this service cannot be observed in the market. However, given the fact that either the public or the state has property rights to the environmental resource, environmental regulation[4] by the government or the public could make the polluter liable to pay a price for the waste disposal service. The polluter pays the price in the form of either the cost he incurs for complying with the environmental regulation or the pollution tax he pays for not complying with the regulation. Therefore, we could interpret the marginal cost of pollution abatement, or the cost the polluter is willing to incur for

[4] The current literature considers regulations by the government and the public respectively as formal and informal regulation (see World Bank [1999]).

reducing every successive unit of pollution abatement (MCA), as the demand price of the waste disposal service. Figure 1 depicts the demand curve for the waste disposal service as the falling MCA or demand price with respect to the pollution load generated. Alternatively, we could see this curve as depicting the rising MCA with respect to the pollution load reduction.

There is an opportunity cost, or health and other damages, to the public for allowing pollution. The supply price of the waste disposal service is the price charged to the polluter by the government or the public for every unit disposal of waste into the environmental media. Therefore, we could interpret the marginal damages (MD) or the damages from every successive unit of pollution that the public is willing to bear as the supply price of the waste disposal service. Figure 1 describes the supply curve of the waste disposal service as the rising marginal damages (MD) or the supply price with respect to the pollution loads.

We will now illustrate the Pigouvian tax/subsidy framework diagrammatically. In Figure 1, the MCA and MD respectively represent the marginal cost of abatement and marginal damages from pollution. E^m and E^* stand respectively for pollution loads with and without tax instrument while 't' stands for the pollution tax. With the polluters using the pollution abatement technologies, the optimality or maximization of welfare requires the pollution to be reduced up to the level at which the MCA equals the MD as Figure 1 shows. If the government levies a tax equivalent to 't' on per unit of pollution on the polluter based on the polluter pay principle, the polluter has an incentive to reduce pollution up to the optimal level, E^*, in the free market. The polluter has two choices: pay a tax equivalent to E^*ERE^m or reduce the pollution load from E^m to E^* incurring the cost equal to E^*ESE^m. If the polluter reduces the pollution, s/he will save a cost equal to ERS as in Figure 1. Therefore, given the tax rate equivalent to 't', the polluter chooses to reduce pollution rather than pay the tax.

A large number of people feel the damages from pollution, which is more so in the case of water and air pollution. Therefore, the damages from a unit of pollution at margin are the sum of marginal damages to all the affected people. Hence, to design a Pigouvian tax, we require information about the abatement cost functions of polluting firms and damage functions for all the affected people. The cost of collecting information to estimate these functions can be prohibitively high. For example, the pollution of a major river like the Ganges or an urban air shed like Delhi can affect millions of people. It may not be economically feasible to design a Pigouvian tax in such instances.

2.1.2.2 Quantity Based Instruments

D.H. Dales (1968) has suggested an alternative to the pollution tax in a system of tradable pollution rights for the management of the environment. He has proposed that property rights should be extended to the use and abuse of the environment and that such entitlement should be offered for sale to the highest bidder. This system is like a tax in order to achieve the specified environmental target at a minimum cost. For example, in the case of air pollution, this approach first determines the optimal level pollution in a given geographical area. The authorities then divide this level of pollution to be tolerated into a number of permits among the various polluting units within the area (either by free distribution or by auctioning). Firms which are already comparatively more efficient in controlling their wastes or pollution (that is, the ones that face a lower unit cost for pollution control) may continue their original level of production and emissions. But they may have some extra pollution permits (or entitlements) to spare. They can sell such extra permits to firms which are less efficient in controlling their wastes (that is, the ones that face a higher unit cost for pollution abatement). Provided monitoring is possible and effective, the net result is that total pollution is kept within the prescribed levels. The more efficient firms will sell their surplus permits to less efficient firms which require more permits in order to continue with their original production plans. This process creates a market for pollution permits in which trading in permits takes place up to the point at which the aggregate supply of permits is equal to the aggregate demand for permits and the equilibrium permit price is equal to the marginal cost of abatement to each firm.

2.1.2.3 Mixed Instruments: A Practical Approach

In practice, we should have a mixture of both command and controls (CAC) and economic instruments. Economic instruments alone may not be feasible because their imposition requires a lot of information on firm level emission, technology, etc., which are not easy to come by. Command and control measures alone are inefficient because they may result in the use of costly pollution abatement technologies by firms. Similarly, it is difficult to estimate the damages to affected people in the case of the pollution tax or to know beforehand the optimal level of pollution in the case of tradable permits, which pose practical problems with regard to the design of economic instruments. Instead, setting pollution standards by Pollution Control Boards and using either the pollution tax or the marketable permits instrument to induce the polluting industry to meet those standards is a hybrid method, which combines both regulatory and economic instruments. However, in such cases, the criteria for fixing environmental standards can become a subject of debate, that is, whether they have to be decided on a scientific basis or on the basis of a referendum or political process. A scientific approach would require that they be based on evidence concerning the effects of air pollution on health or of polluted water on fish and human life. Alternatively, the community or society concerned could decide on them through a political process, which involves a referendum on alternative sets of pollution standards. Among other issues to be sorted out would be the question of whether the standards should be fixed at the state levels or the national and whether the standards should constitute a compromise between industry and people, etc.

Once we fix environmental standards on an apriori basis, we would be able to avoid the difficult problem of estimating the damages to all the affected people from pollution in order to design the economic instruments. However, we need an estimate of the pollution abatement cost. It is economically feasible to obtain an estimate of pollution abatement costs because (a) the polluters may normally be much less in number than the affected people; and (b) we can obtain tangible information about technologies used by the polluters, the pollution loads and the levels of production. Using firm-level data on pollution loads, we can estimate costs of abatement and production levels and the pollution abatement cost functions using econometric techniques. Given the environmental standards and the estimated marginal abatement cost function, we can fix a rate of tax such that the firms will automatically have an incentive to reduce pollution in order to meet the standards. This is explained in Figure 2.

Let us assume the emission standard is OE. Let the current rate of the firm's emission be OD. If the firm has to reduce the pollution load from D to E as per the environmental standard, the rate of tax equivalent to OA will make the firm do so. The firm has an incentive to abate pollution rather than opting to pay the tax because the cost of abatement given by the area BFDE in the Figure is lower than the tax liability given by the area BCDE. Similarly, firms can use marketable pollution permits to obtain the reduction in pollution loads as required by the environmental standards. Researchers have shown that the taxes standard or the tradable permits and emission standards method result in the adoption of least cost technologies by the firms[5].

There can be many situations in which command and control instruments are unavoidable. In some cases, the social cost of a particular activity depends on factors that are beyond the control of those directly involved. For example, the effects of the discharge of effluents into a river may depend upon the conditions of the river at that particular point in time. Similarly, stagnant air can trap pollutants, perhaps even collect them, which becomes hazardous. Therefore, exogenous meteorological conditions could contribute to occasional crises requiring temporary emergency measures in the form of command and controls. Pollution tax rates cannot be changed at short notice to deal with such emergencies. Even if the government were to effect changes, there would be a time-lag before the polluters respond to the change. Marketable permits also result in long-term adjustments in environmental quality and are not suitable for emergencies. The government, on the other hand, can quickly activate command and control measures to deal with more than normal amounts of emissions arising out of emergencies since such measures do not require extra monitoring. Therefore, in practice, neither economic instruments nor command and controls alone constitute an optimal environmental strategy. Hence, the cost-minimizing strategy to realize given environmental standards is a mixed strategy consisting of economic instruments and command and controls.

2.1.3 Community Action or People's Participation

According to conventional thinking, when it comes to environmental management, the government has the power to design and implement the command and control measures and the economic instruments described above. This is on the assumption that the government is benevolent and that there are supporting legal and other instruments. In many countries, however, the government may not be benevolent and/or the required environmental laws may not be in place. Moreover, even if such laws were in place, they might be ineffective due to a variety of reasons. In such instances, it is important to look for institutional alternatives to government in order to control environmental externalities. The alternatives can be (a) collective action on the part of all the agents responsible for managing the environment; and (b) a purely market option.

Coase (1960) has argued that many types of externalities can be optimally controlled by creating specific property rights among the concerned agents. Property rights mean either the people's right to clean water and air or the producer's and consumer's right to pollute. We can state this important finding of Coase, now known as the Coase theorem, as follows: consider the situation of an externality such as pollution. There are two agents involved here, namely, the generator and the affected parties. Given the initial property right to any resource either to the generator of the externality or to the affected party, if the cost of bargaining is zero, the bargaining between the two parties results in the optimal control of the externality. The final outcome of the bargaining is invariant vis-à-vis the initial property right, that is, whether the right to clean air is vested in the affected people or whether the right to pollute is given to the polluter. Figure 3 further explains this result. In this Figure, we measure the pollution load along the x-axis and the marginal cost of pollution abatement (MCA) and the marginal damages (MD) along the y-axis. It gives the optimal pollution load as OE. For pollution loads higher and lower than OE, there are incentives for gainful bargaining between the polluter and the affected party. If the polluter has the right to pollute beyond OE, then the MD is higher than MCA for the pollution loads and the affected

[5] For more details, see Baumol and Oates, 1988.

party has an incentive to bribe the polluter at any rate lower than MD for a unit reduction in pollution while the polluter has an incentive to accept the bribe at any rate higher than the MCA. Therefore, bargaining between the two parties takes place until the pollution load is reduced to OE. Similarly, since MCA is higher than MD for the pollution loads lower than OE, the polluter has an incentive to offer bribes to the affected party at any rate lower than MCA while the affected party has an incentive to accept bribes at any rate higher than MD. Again, the bargaining between them leads to the optimal pollution load OE.

The Coasean bargaining theorem may not work in practice to control environmental externalities for several reasons. First of all, in reality, the transaction costs or costs of bargaining are not zero but positive. We can show that with positive costs of bargaining, the resulting pollution load through bargaining can be higher or lower than the optimal pollution load 'OE' depending on the initial property rights.

This means that with the positive transaction costs, the final result will no longer be invariant with respect to the initial property rights. Secondly, one of the key assumptions in the Coasean solution is that the value of property rights captures all the externalities and that there are incentives for gainful bargaining. This can work well for externalities on a smaller scale or local externalities of the type described by Coase such as a building that blocks the windmill's air currents or a confectioner's machine that disturbs the doctor's quiet, etc. However, many environmental externalities occur on a grander scale with a large number of receivers and, many times, a good number of generators (as, for example, in the case of the pollution of a river and the atmosphere) which makes defining property rights and facilitating bargaining difficult. One way to deal with this problem is to create a common property right to the river of all the affected people as one group and an association of polluters of the river as another group so that the bargaining to reduce river pollution can take place between the two parties. The third problem with the Coasean bargaining again arises in the context of defining property rights for an environmental resource. An environmental resource is a stock affecting the welfare of both the present and future generations. Capitalization of future benefits from this resource is not possible because property rights to future generations of affected people cannot be defined. One approach to taking care of future generations is to consider the government as its representative. The government can compete in the market on behalf of future generations for the environmental property rights and to pay for these rights by issuing a debt which the future generations must service. Another approach to environmental property rights of future generation is based on the assumption that the present generation has a bequest motive towards the future and wants to bequeath to the future the preserved resources. However, both government intervention and bequest motive are outside the scope of Coase's property rights approach.

In the Coasean bargaining solution, the government has a minimal role to play. Its role is only to create property rights and to protect them while free-market bargaining between the agents will optimally control the externality. Various institutional alternatives now considered in the literature for the control of environmental externalities contain some elements of the market mechanism with the government playing only a limited role. Given the ineffectiveness of government in environmental management and the high transaction costs of government instruments, it is imperative to look for new institutions to define and implement property rights for environmental externalities. Researchers have found collective action by all the agents involved to be one such new institution.

3. Estimating Pollution Taxes for Air Pollution Abatement

The environment provides waste disposal services as productive inputs to industry. Given environmental regulation, producers place a value on these inputs just as they value other conventional inputs such as labour, man-made capital and materials. Environmental regulations meant to ensure environmentally sustainable industrial development impose a cost on industry. UN methodology for integrated environmental and economic accounting (1993) calls this cost a maintenance cost or the cost to the industry for maintaining the quality of the environment at its natural regenerative level. As explained in Section 2, we need environmental regulation via pollution taxes or other instruments in order to make the industry internalise this cost. There is a need to estimate shadow prices of environmental inputs in order to arrive at the maintenance cost to the industry and to estimate the pollution abatement cost functions for the purpose of designing pollution taxes.

We can use a model describing the technology of power generation as one of jointly producing good output, that is power, and bad output, that is pollution load, in order to estimate the shadow prices and marginal pollution abatement cost functions of industrial pollutants. The theory of production calls this model the output distance function. The production relation expressed in the reduced form as the output distance function indirectly considers the processes of waste generation or material balance[6]. This model defines the producer demand price for waste disposal services from the environment as the opportunity cost in terms of good output foregone in order to reduce bad output. We may regard this price as the shadow price of pollution or the marginal cost of pollution abatement. Using the estimate of this model, we can obtain estimates of the marginal cost of abatement of industrial pollutants. Appendix A describes the output distance function and its estimate for the thermal power generating industry in the state of Andhra Pradesh (AP), India[7]. Table 1 provides estimates of shadow prices of pollutants SPM, SO_2, and NO_x for thermal power generation in AP.

3.1 Cost of Environmentally Sustainable Power Generation

Environmental standards such as the Minimum National Standards (MINAS) of India or the WHO standards are scientifically designed instrument to capture the natural regenerative capacity of environmental media. Therefore, we may interpret the cost to the industry of complying with these standards as the cost of environmentally sustainable industrial development. One has to account for this cost in the measurement of Green GDP or in the environmentally corrected net national product (ENNP). We could define the ENNP as[8]

$$ENNP = C + P_k \nabla K + P_n \nabla N \quad (1)$$

where C, ∇K, and ∇N represent respectively consumption, changes in manmade capital, and natural or environmental capital while P_k and P_n are prices of manmade and natural capital.

The first two terms in equation (1) constitute the conventional NNP while the last term accounts for the value of change in natural resource stock (i.e., change in environmental quality) due to

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6 Murty and Russell (2000) have shown that there could be problems in defining the shadow prices of pollution and finding the trade-off between pollution and output along the production frontier in this model. However, they have also shown that modeling abatement as an intermediary input does yield a positive trade-off and facilitates the definition of shadow prices of pollution.

7 See Murty and Gulati, for details (2007).

8 See Witzman (1976), Dasgupta and Maler (1998), and Murty and Surender Kumar (2004).

various economic activities during the year. The UN methodology suggests the development of physical and monetary accounts of natural capital as satellite accounts to conventional national accounts in order to estimate $P_n \nabla N$. It is necessary to develop time series of physical accounts of ambient quality of atmosphere, water resources and forest cover in order to estimate ∇N. For example, in the case of air pollution, we could measure ∇N as the pollution load of SPM that is in excess of the pollution load corresponding to safe ambient standards. In the case of CO_2, ∇N could be simply the pollution load generated because it adds to the stock of CO_2 already present in the atmosphere.

Table 2 provides physical and monetary accounts of air pollution for a representative firm belonging to the AP power-generating industry during a given year. We estimated the annual cost of reducing the pollution levels of SPM, SO_2, and NO_x from the current levels to zero in all thermal power generating plants in AP as Rs. 534 million. We could interpret this cost as the cost of environmentally sustainable thermal power generation in AP.

3.2 Shadow Prices of Pollutants and Pollution Taxes

Estimation of pollution taxes using the Taxes-Standards Method requires estimates of the marginal cost of pollution abatement and data about pollution standards. It is possible to interpret the shadow prices of pollutants that we report in Table 1 as the marginal costs of pollution abatement. Using the estimated distance function in Appendix A for thermal power generation in AP, we could calculate plant specific shadow prices. We could obtain the marginal cost of pollution abatement function for each pollutant by finding a relationship between the shadow price of pollutant and pollution load. The marginal cost of pollution abatement of a plant depends on output, pollution and plant-specific characteristics among others. Specifying this relationship as stochastic, we estimate the marginal cost of the pollution abatement function for SPM, SO_2 and NO_x separately as given in equations 2, 3 and 4 respectively with regard to thermal power generation in AP. In these equations, the dependent variables are shadow prices or marginal costs of pollutants (SPMS, SO_2S and NO_xS) while the independent variables are electricity output (OUT), pollution concentrations (SPMC, SO_2C, NO_xC), plant specific dummy variables (D_i, i = 1….4) and time (TIME). There is a rising marginal cost with respect to pollution reduction

<u>SPM</u>

In SPMP = 11.82 + 0.255* In (OUT) - 1.02* (SPMC) + 0.705*DI - 0.308*D2 - 0.57*D3
(22.80) (2.92) (-13.71) (2.96) (1.00) (-3.31)
0.108*D4 - 0.22* TIME
(0.55) (13.71) 2
Adjusted R^2 = 7822

Figure 4 depicts the marginal pollution abatement cost function for SPM. y-axis measures the marginal cost of abatement while x-axis measures the SPM concentration.

<u>SO_2</u>

In SO_2P = 9.33 - 1.012* In (OUT) - 0.835* In (SO_2C) - 02.16*DI - 2.27*D2 - 1.69*D3
(27.24) (11.73) (-14.85) (-8.37) (-6.68) (-10.13)
0.352*D4 - 0.073* TIME
(-1.47) (-3.01) 2
Adjusted R^2 = 0.8196

NO_x

$$\ln NO_xP = 4.94 + 1.21^* \ln(OUT) - 0.63^* \ln(NO_xC) + 3.88^*DI - 2.41^*D2 - 0.93^*D3$$
$$(14.67)\quad (13.48)\qquad (-10.67)\qquad (-16.58)\quad (-7.50)\quad (-5.23)$$
$$0.108^*D4 - 0.22^*\,TIME$$
$$(6.34)\qquad (10.8) \qquad\qquad 2$$

Adjusted $R^2 = 0.8062$

Using the above marginal abatement cost of functions and using the MINAS Stack Emission Standards of 115, 80 and 80 milligrams per NM3 respectively for SPM, SO_2 and NO_x, we compute the tax rates as Rs. 2099, 20519 and 5554 per tonne of emissions. If the state of AP levies these taxes on the power-generating company, the company has incentives to internalize the cost of pollution abatement as we discussed in Section 2.

4. Collective Action: A Deterrent to Collusion Between Industry and Corrupt Bureaucracy[9]

Governments of many developing countries, perhaps some in even developed countries, are non-benevolent, so that the responsibility of dealing with market failure and achieving developmental objectives cannot be completely left to their discretion. When it comes to issues such as the control of externalities like environmental pollution, the corrupt bureaucracy of developing countries often colludes with external diseconomy- creating agents to increase the externality problem rather than to control it. In such situations, there is no option left to the parties affected by the externality but to fall back on either collective action or political influence in order to deal with the bureaucracy and the perpetrator of the externality. As already explained in Section 2, Coase (1960) argues that given the initial property rights of both the externality generator and the receivers, the costless bargaining between the parties in a free market will result in the optimal control of the externality, the final outcome being independent of the initial allocation of property rights. Becker (1983) has shown that the political influence exerted by pressure groups can have an impact similar to that exerted by a benevolent government to deal with market failure. To quote him, "The same analysis of competition among pressure groups, without the introduction of the social welfare function or benevolent government, explains expenditures on defense and other public goods, taxes on pollution, and other government activities that raise efficiency, even when some groups are hurt by the activities" (Becker, 1983).

However, as Coase points out, bargaining is not always costless. In the world of Coase and Becker, therefore, transaction costs are very much a factor to be considered. But even with transaction costs, there can be significant net welfare gains from collective action, and the case for collective action will be reinforced if the government is non-benevolent. Take the case of industrial water pollution abatement in India. More than twenty years of environmental legislation in India have not produced a pollution tax while the CAC methods used so far by the Indian government have not made a dent in industrial pollution control. This has also been the case with many other developing countries. One important reason for this is the absence of awareness among people about the extent of damage from pollution and their inability to organize themselves into pressure groups to participate in the management of pollution abatement. In such a situation, the industry and the non-benevolent bureaucracy have incentives to collude in the violation of environmental standards. The industry can bribe the regulator to either over report its effluent

[9] This section is drawn mainly from Murty (1995b).

quality or not report it at all. There are several agents involved in the political economy of industrial pollution abatement: the affected people, elected representatives, the bureaucracy and the industry. Incentives exist for a sub-coalition of agents such as a coalition of affected people and elected representatives or another coalition of bureaucracy and industry. Such conditions are fertile grounds for the emergence of politically active pressure groups. As Murty (1995b) has shown, competition among these pressure groups may result in the optimal control of pollution.

4.1 Pollution Taxes, Corruption, Bribes and Penalties

In the case of non-benevolent government, which might be the case in many developing countries, the mere enactment of environmental laws does not guarantee their actual execution or implementation. There are many views on the whys and wherefores of corruption in bureaucracy. According to one view, in the pyramidal structure of bureaucracy, corruption increases as one goes down the ladder while it is virtually zero at the top. Opportunities for corruption arise when the principal officer delegates enforcement authority to officers lower down in the cadre (Rose-Ackerman, 1978; Milgrom and Roberts, 1988). In such a system, checks and balances operate to minimize corruption because the probability exists that the bribe-taking junior officer can be apprehended in the act and penalized by the superior officer. Mukherjee and Png (1994) have shown, on the other hand, that in a pyramidal structure of corruption, the penalty for bribe-taking, or compensation for the honesty, of lower-ranking officers that regulators might resort to have only uncertain effects on pollution abatement. Another view posits that corruption is distributed (perhaps evenly) among officers of all ranks of the bureaucracy. According to this view, there is tacit agreement among the officers to share the bribe collected once a lower-ranking officer, say an inspector, accepts the bribe. Some would argue that it is bureaucratic corruption of this form that is rampant in many developing countries. In India, the commonly held public view subscribes to this latter theory. The third view sees corruption as a matter of collusion between the bureaucracy and the politicians (that is, members of the legislature), the motive for collusion on the part of the elected representatives arising from a desire to seek a profit from the power granted to them constitutionally. This type of corruption can take place in the societies where the public is not politically aware or organized to deal with erring legislators, which is the case with the emerging democracies of many developing countries. Reins on the latter two types of corrupt bureaucracy are only possible through civil society activism, especially by people who are the direct victims of industrial pollution.

In the case of democracies where people affected by an externality are politically active, they can influence their elected representatives to stem bureaucratic corruption. They can bring pressure on their elected representatives, say, a municipal committee in the case of a local externality, to impose penalties on bribe-taking bureaucracy. Alternatively, they can organize themselves into a pressure group to take legal action against the colluding elected representatives, bureaucracy and industry. Thus, depending on the way corruption actually takes place, there can be sub-coalitions of agents who play a role in industrial water pollution abatement: a coalition of affected people and elected representatives and a coalition of industry and bureaucracy. In an alternative scenario, on the other hand, it might be the affected people alone on one side who are opposed by a coalition of industry, bureaucracy and elected representatives on the other. Collective action on the part of the affected people moreover has transaction costs in the form of time devoted and efforts made to organize in order to detect the violation of environmental standards by a coalition of bureaucracy and industry and to effect legal action.

4.2 Public Perception of Damages and Penalties

Consider a situation in which four sets of agents are involved in industrial pollution abatement: (a) affected public; (b) elected representatives of the public (say a municipal committee); (c) bureaucracy (i.e., the executive body implementing the environmental legislation); and (d) industry. In a situation where there is no attempt by the affected public to check the pollution, the bureaucracy and industry could interpret it as an invitation to violate the environmental standards.[10] Considering that environmental legislation levies a pollution tax, the industry has an incentive to bribe the bureaucracy, at a rate less than the tax per unit of effluent for over-reporting its effluent quality. A false certification of higher effluent quality by bureaucracy helps the industry to shun its responsibility towards meeting the standards. The extent to which the affected public can make the bureaucracy and industry comply with environmental standards depends upon its degree of perception of damage and the influence it can exert either through civil society activism, or elected representatives, or both. The degree to or the probability with which the affected people perceive the damage and are able to rein in the bribe-taking bureaucracy and non-complying industry depends upon the amount of time and effort they are able to devote to politically organize themselves. Politically active affected people can exert pressure on their elected representatives to impose penalties on the bureaucracy and industry if they are caught colluding to violate the set standards.

4.3 Non-benevolent Governments and Strategic Behavior of Active Groups in Water Pollution Abatement

If the bureaucracy or the regulator is corrupt, incentives exist for the formation of sub-coalitions of the various agents who are party to industrial water pollution[11]. As explained earlier, it is possible that the affected people and the municipal committee will act in tandem. Just as people need the help of their representatives to deal with the industry and the bureaucracy, the representatives require the people's support to get re-elected. Similarly, it is possible that the industry and bureaucracy have incentives to collude in the form of sharing the cost saved from non-compliance with environmental standards by the industry. We resort to this simple bifurcation of the domain of political action into two sub-coalitions in order to highlight the effect of the political activity of pressure groups on industrial water pollution abatement. However, in actuality, other sub-coalitions are possible and we can attempt a similar analysis with them. Thus we have two groups of agents: Group I, which is made up of the affected people and the municipal committee, with a strategy of time devoted for political organization, W, and cost function, G^1. Group II is made up of the industry and bureaucracy with a strategy of level of environmental quality attained by industry, E, and cost function G^2. The cost to each group depends on the W, E and penalties and bribes[12]. Given penalties and bribes, Group I minimizes G^1 with respect to W given E while Group II minimizes G^2 with respect to E given W. The strategic behavior of Groups I and II yields the reaction functions $\mathrm{W(E)} = \dfrac{\delta G^1}{\delta W}$, $\mathrm{W}^{/}(\mathrm{E}) \leq 0$ and $\mathrm{E(W)} = \dfrac{\delta G^2}{\delta E}$, $\mathrm{E}^{/}(\mathrm{W}) \geq 0$.

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10 We confine ourselves here to the second view of corruption for a detailed analysis. It is possible to undertake a similar analysis with respect to the third view on corruption.

11 The structure of corruption in bureaucracy assumed here is different from the one considered in some recent work in this area. This study assumes that the bribes that the bureaucracy accepts are shared by all cadres of officers while some recent studies consider a pyramidal structure of corruption (where corruption reduces as one climbs up the bureaucratic ladder, becoming virtually zero at the top).

12 See Appendix B.

As Figure 4 illustrates, we can define the equilibrium strategies of a two-person Nash non-cooperative game as $W^*(E^*)$ and $E^*(W^*)$ which are given by the intersection of curves depicting the reaction functions of Groups I and II. Increasing the penalties on industry and bureaucracy have the effects of increasing the environmental quality E, given W, and decreasing the time devoted to political activity W, given the environmental quality E. The equilibrium environmental quality of a two-person Nash non-cooperative game increases as the penalties increase. Thus, there are welfare gains from increasing penalties either in the form of a decrease in damages to environmental quality, or in the form of a saving in cost of political activity. Since there are costs to the industry from increasing E, there can be net welfare gains from increasing penalties so long as the incremental damage reductions to affected parties are higher than the incremental cost to the industry. In fact, the condition that the marginal cost of abatement to industry be equal to the marginal reduction in damages determines the optimal rates of penalties and optimal environmental quality. However, in the current framework, the statutorily fixed environmental standards determine the optimal rates of penalties. This analysis therefore shows that even if the government is non-benevolent, concerned parties could achieve the statutorily fixed environmental quality through political competition[13].

4.4 Coase and Becker in Practice: Some Examples from India

Empirical findings of a survey of some industrial estates in India[14] provide evidence for the effectiveness of active pressure groups when it comes to controlling the externality of industrial pollution. Data from this survey provides insights into empirical aspects of the economic and non-economic processes that shape collective action vis-a-vis industrial water pollution abatement. The data shows that collective action of various agents such as people affected by water pollution, elected representatives, industries, the NGOs and the government was responsible for triggering the processes that led to the control of industrial water pollution. The survey shows that factories in the industrial estates were discharging untreated waste water which deposited on the surface of land and in the local streams, resulting in the degradation of cultivable lands and the contamination of ground water sources. But while the local people had suffered from crop and cattle losses in addition to contracting a variety of water-borne diseases, the government had failed to take cognizance of the damages, which appear to support the local people's view that there was collusion between the factories and government officials to share the cost saved by factories from non-compliance with pollution standards.

The initial efforts by local people to stem the pollution either through persuasion or even through physical threats to factory owners did not yield any results. An organized group of local people therefore resorted to legal action by filing public litigation cases in courts. There are now a number of successful public litigation cases dealing with industrial water pollution abatement in India. In one such public litigation case (Supreme Court,1990) concerning an industrial estate in Hyderabad, India, the Supreme Court ordered the constitution of an expert committee (NEERI, 1991) to study the problem of water pollution and to make recommendations regarding a) the extent of compensation to be paid to the affected people by the industries; and b) the remedial measures that the industries and the government had to take in order to prevent water pollution in the future. After receiving the Committee's recommendations, the Supreme Court directed the factories to pay compensation to the affected people and asked the government to take action as

13 See Murty (1995b) for proof.

14 We base this on a survey conducted in 1996 by the Institute of Economic Growth, Delhi, of seventeen highly water-polluting industries in India.

per existing environmental laws against the factories so that they comply with pollution standards. The political organization of the affected people in this particular instance also enlisted the active support of their elected representatives (members of the local state assembly and Union parliament) in the interest of industrial water pollution abatement. Elected representatives in turn have made local pollution control problems part of their election manifestos. There was, therefore, a coalition of affected people and elected representatives to deal with a coalition of factories and bureaucracy to control water pollution in this industrial area. The emergence of such an institutionalized setting, in which there was competition among pressure groups or interest groups, have resulted in the adoption of common effluent plant technology (CETP) by factories in each of the industrial estates. Collective action by the affected people has induced the factories to organize themselves as a club to construct and manage a CETP[15]. It is also interesting to note that there are many instances now in India where the government plays a catalytic role rather than its conventional coercive role in environmental management by providing financial and other incentives to a club of factories to install a CEPT[16].

5. Conclusions

Economic instruments such as pollution taxes and marketable permits, on the one hand, and institutions facilitating people's participation, on the other, are two efficient methods for controlling environmental pollution. Coase's bargaining methods with participatory institutions result in decentralized solutions which carry significant savings in transaction costs as opposed to the Pigouvian taxes. There is enough empirical evidence from the developing countries to support this form of environmental regulation through people's participation (Murty *et al.,* 1999; WB, 1999).

The method for estimating pollution taxes for the thermal power-generating industry in India described in this paper underscores the informational requirements for designing such taxes. There is a cost associated with environmentally sustainable industrial development that the UN methodology of Integrated Environmental and Economic Accounting calls the maintenance cost. We could consider this cost as the cost to the industry of complying with the environmental standards taking into account the natural regenerative capacity of environmental media. This paper uses a method in the theory of production which describes pollution as a bad output that is jointly produced with the good output in order to estimate the maintenance cost. We use panel data for 8 years from 5 coal-fired thermal power plants in the state of Andhra Pradesh, India, for the estimation. We estimate the shadow prices of pollutants and the cost of pollution abatement for AP GENCO. We calculate the pollution taxes that would make the thermal power plants in AP comply with the MINAS stack standards as Rs. 2099, 20519 and 5554 respectively for SPM, SO_2 and NO_x.

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15 Adun Roud, of the Centre for Development and Environment, of the University of Oslo, while commenting on an earlier version of this paper, noted that this kind of collective action had actually taken place among people affected by industrial pollution along the Hoogly River in the southern parts of Calcutta before a well-known environmental lawyer M.C. Mehta actually brought the cases to the Supreme Court of India. The court rulings for 1994 urged several heavily water polluting units along the Hoogly River to install the required pollution control equipment. Later, the West Bengal Pollution Control Board insisted on implementing the court rulings by threatening to close down 12 major polluters unless they took significant steps to reduce water pollution. Thus, he feels this is the first instance where collective action succeeded. However, he observes that the relatively strong political influence of the industrial lobby vis-à-vis the relatively weak position of the environmental lobby significantly influences the speed of the environmental process.

16 Mishra and Murty, 1999.

We measure the political activity of people affected by an externality in terms of a fraction or the number of people who perceive damages from the externality or the probability at which they can apprehend the colluding industry or the bureaucracy. There is a cost to political activity in terms of the time devoted to it by the affected people. A sub-coalition of affected people and elected representatives can impose penalties on the bureaucracy and industry if this coalition can prove that the bureaucracy was accepting bribes and if they can prove that the industry was over-stating the effluent quality.

The Nash non-cooperative game among the sub-coalitions of agents yields an equilibrium environmental quality which is superior to the environmental quality without political activity. As the rates of penalties increase, the equilibrium environmental quality of the game increases. There can be rates of penalties and a level of political activity with respect to which governments/ concerned parties can set statutorily fixed environmental standards. Moreover, the rate of penalty required to achieve the statutory environmental quality through competition between the pressure groups in the case of a non-benevolent government is the same as the rate of tax required, using the taxes standard approach, with a benevolent government.

Out of two approaches to environment management described in this paper, economic instruments score well in situations of good and responsible governments and no resource constraints on environmental management. However, this is not usually the scenario currently found in many developing countries. Community action arising out of competition among pressure groups discussed in this paper scores well for the environmental management in developing countries. Participatory approaches with decentralized solutions result in the savings of transaction costs of environmental management and work well even if government is inefficient. Even in countries with good governments, cost effective environmental management requires using of a combination of economic instruments and participatory approaches.

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APPENDICS

Appendix A: Output Distance Function and Estimation for Thermal Power Generation in AP

Suppose that a firm employs a vector of inputs $x \in \Re^N_+$ to produce a vector of outputs $y \in \Re^M_+$, and $\Re^N_+$ and $\Re^M_+$ are non-negative N- and M-dimensional Euclidean spaces, respectively. Let P(x) be the feasible output set for the given input vector x and L(y) the input requirement set for a given output vector y. Now the technology set is defined as

$$T = \{(y,x) \in \Re^{M+N}_+ \; y \in P(x)\}. \qquad (A1)$$

The output distance function is defined as,

$$D_O(x,y) = \min\{\lambda > 0 : (y/\lambda) \in P(x)\} \forall \, x \in \Re^N_+. \qquad (A2)$$

Equation (A2) characterizes the output possibility set by the maximum equi-proportional expansion of all outputs consistent with the technology set (A1).

The assumptions about the disposability of outputs become very important in the context of a firm producing both good and bad outputs. The normal assumption of strong or free disposability about the technology implies,

$$\text{if } (y_1, y_2) \in P(x) \text{ and } 0 \le y_1^* \le y_1,\ 0 \le y_2^* \le y_2 \Rightarrow (y_1^*, y_2^*) \in P(x).$$

It means we can reduce some outputs given the other outputs constant. This assumption may exclude important production processes such as undesirable outputs like pollution. The assumption of weak disposability is relevant to a discussion of such production processes. The assumption of weak disposability implies,

$$\text{if } y \in P(x) \text{ and } 0 \le \lambda \le 1 \Rightarrow \lambda y \in P(x).$$

It means that a firm can reduce the bad output only by decreasing simultaneously the output of desirable produce.

The idea of deriving shadow prices using output and input distance functions and the duality results is originally from Shephard (1970). A study by Fare, Grosskopf and Nelson (1990) is the first to compute shadow prices using the distance function and non-parametric linear programming methods. Fare *et al.* (1993) was the first study to derive the shadow prices of undesirable outputs using the output distance function.

The derivation of absolute shadow prices for bad outputs using distance function requires the assumption that the one observed output price is the shadow price. Let y_1 denote the good output and assume that the observed good output price (r_1^0) equals its absolute shadow price (r_1^s) (i.e., for m=1, $r_1^0 = r_1^s$). Fare *et al.* (1993) have shown that the absolute shadow prices for each observation of undesirable output (m=2,.....,M) can be derived as[17],

$$(r_m^s) = (r_1^0) \bullet \frac{\partial D_0(x,y) / \partial y_m}{\partial D_0(x,y) / \partial y_1}. \qquad (A3)$$

The shadow prices reflect the trade-off between desirable and undesirable outputs at the actual mix of outputs, which may or may not be consistent with the maximum allowable under regulation (Fare *et al.,* 1993). Further, the shadow prices do not require that plants operate on the production frontier.

[17] See Fare (1988) for derivation.

Estimation Procedure and Data

In order to estimate the shadow prices of pollutants (bad outputs) for thermal power generation in Andhra Pradesh using equation (A3), we need to estimate the parameters of output distance function. We give the trans-log functional form[18] used for estimating these functions as follows:

$$\ln D_o(x, y) = \alpha_0 + \Sigma\beta_n \ln x_n + \Sigma a_m \ln y_m + 1/2\Sigma\Sigma\beta_{nn'} (\ln x_n)(\ln x_{n'}) + 1/2\, \Sigma\Sigma\alpha_{mm'} (\ln y_m)(y_{m'}) + \Sigma\Sigma\gamma_{nm}(\ln x_n)(\ln y_m) + \iota_1 d_1 + \iota_2 d_2 + \iota_3 d_3 + \iota_d 4 \qquad \text{(A4)}$$

where x and y are respectively, Nx1 and Mx1 vectors of inputs and outputs. There are three inputs: capital, labor, and energy and four outputs: good output, electricity, and bad outputs, SPM, NO_x , and SO_2, while d_i is the dummy variable representing the plant. We use a linear programming technique to estimate the parameters of a deterministic translog output distance function (Aigner and Chu, 1968). We accomplish this by solving the problem,

$$\max \Sigma[\ln D_o (x , y) - \ln 1], \qquad \text{(A5)}$$

subject to

(i) $\ln Do (x, y) \leq 0$

(ii) $\underline{(\partial \ln D_o (x, y))/(\partial \ln y_1)\ ^3 \leq 0}$

(iii) $(\partial \ln D_o (x, y))/(\partial \ln y_i) \leq 0$

(iv) $(\partial \ln D_o (x, y))/(\partial \ln x_i) \leq 0$

(v) $\Sigma\alpha_m = 1$

$\Sigma\alpha_{mm} = \Sigma\gamma_{nm} = 0$

(vi) $\alpha_{mm} = \alpha_{mm}$

$\beta_{nn} = \beta_{nn}$

Here the first output is desirable and the rest of (M-1) outputs are undesirable. The objective function minimizes the sum of the deviations of individual observations from the frontier of technology. Since the distance function takes a value of less than or equal to one, the natural logarithm of the distance function is less than or equal to zero, and the deviation from the frontier is less than or equal to zero. Hence, we maximize the objective function implying the minimization of the sum of deviations of individual observations from the frontier of technology. The constraints in (i) restrict the individual observations to be on or below the frontier of the technology. The constraints in (ii) ensure that the desirable output has a non-negative shadow price. The constraints in (iv) restrict that the shadow prices of bad outputs are non-positive, i.e., weak disposability of bad outputs whereas the restrictions in (v) are the derivative property of the output distance function with respect to inputs, i.e., the derivatives of output distance function with respect to inputs is non-increasing. The constraints in (v) impose homogeneity of degree +1 in outputs (which also ensures that technology satisfies the weak disposability of outputs). Finally, constraints in (vi) impose symmetry. There is no constraint imposed to ensure non-negative values to the shadow prices of undesirable outputs.

[18] Many earlier studies for estimating shadow prices of pollutants have used the translog functional form for estimating the output distance function. These include Pitman (1981), Fare *et al.* (1990), and Coggins and Swinton (1996).

Table A1: Descriptive Statistics of Variables Used in the Study

Variable	Unit	Mean	Standard Dev.	Maximum	Minimum
Electricity	Million Units	298.28	13.91	933.58	0.01
SPM	Tonnes	653	0.033	3.526	0.018
SO2	Tonnes	874	0.049	4.268	0.004
NOxC	Tonnes	139	0.013	1.984	0.001
Coal	Tonnes	223460	9.93	667.05	0.01
Capital	Rupees millions	1913.231	905.46	62395.28	148.59
Wage Bill	Rupees millions	255.628	111.03	9332.04	344.16

We estimate the output distance function described above by considering electricity as a good output and pollution loads of SPM, NO_x, and SO_2 as bad outputs using data about thermal power generation by APGENCO in the State of Andhra Pradesh. Table A1 provides the descriptive statistics of variables used in the estimation of the distance function. We report the estimates of parameters of distance function in Table A2. Using the estimated distance function, we estimate the shadow price of a pollutant in terms of the units of the good output foregone for one unit reduction in pollution. The computed shadow prices for a representative plant of APGENCO are Rs. 1043.688, 11539.15, and 5866.812 respectively, per ton reduction in SPM, NO_x, and SO_2. The current electricity tariff for industries in AP is on average Rs. 3.60 per unit which is used to compute the shadow prices.

Table A2: Estimates of Parameters of Output Distance Function

Coefficients of the Output Distance Function Model						
Variables	**Description**	**Coefficients**	**Variables**	**Coefficients**	**Variables**	**Coefficients**
Y1	**electricity**	3.025	**X33**	-0.431	**y3x1**	0.167
Y2	**SPM**	1.297	**Y12**	0.032	**y3x2**	-0.268
Y3	**SO2**	1.330	**Y13**	0.004	**y3x3**	-0.100
Y4	**Nox**	0.605	**Y14**	0.163	**y4x1**	-0.085
X1	**Capital**	-1.041	**Y1x1**	-1.095	**y4x2**	0.669
X2	**Wage**	19.104	**Y1x2**	0.820	**y4x3**	-0.290
X3	**Coal**	-0.408	**y1x3**	0.213	**X12**	-1.858
Y11		-0.199	**y23**	0.069	**X13**	1.116
Y22		-0.062	**y24**	-0.038	**X23**	0.402
Y33		0.110	**y2x1**	0.199	**Intercept**	
Y44		0.059	**y2x2**	-0.448		
X11		1.692	**y2x3**	0.051		
X22		7.411	**y34**	-0.183		

Table A3: Description of Variables in the Estimated Distance Function

Names of Variables and their Identification					
Output	Y1	coal2	x33	Socap	Y3x1
SPM	Y2	Outspm	y12	Sowage	Y3x2
SO2	Y3	Outso	y13	Sofuel	Y3x3
NOx	Y4	Outno	y14	Wagecoal	X23
Capital	X1	Outcap	y1x1	Nocap	Y4x1
Wage	X2	Outwage	y1x2	Nowage	Y4x2
Coal	X3	Outcoal	y1x3	Nocoal	Y4x3
Output2	y11	Spmso	y23	Noother	Y4x4
spm2	y22	Spmno	y24	Capwage	X12
So2	y33	Spmcap	y2x1	Capfuel	X13
No2	y44	Spmwage	y2x2		
cap2	x11	Spmcoal	y2x3		
Wage2	x22	Sono	y34		

Appendix B: Coase-Becker Model of Collective Action

We use the following notation to develop a model of collective action in industrial pollution abatement.

$\bar{E}$: Environmental quality corresponding to statutory level of pollution;[19]

$\hat{E}$: Actual environmental quality attained by industry;

E: Environmental quality reported by bureaucracy;

$D(E)$: Actual damage received by affected people, $D^{/}(E) < 0, D^{//}(E) > 0$

$A(E)$: Cost of treatment of effluent to the industry, $A^{/}(E) \geq 0, A^{//}(E) \geq 0$

W: Time devoted by affected people for political organization

$V(W)$: Cost of political organization

$\lambda(W)$: Probability with which affected people (or a fraction thereof) perceive damages from the degraded environment; $0 \leq \lambda \leq 1$

t: Pollution tax per unit of effluent

b: Bribe received by bureaucracy from industry per unit of over-reporting of environmental quality

p: Penalty on bureaucracy per unit of under-reporting of environmental quality

s: Penalty on industry per unit of non-disclosure of effluent quality

Now, we can identify the cost and benefits to various agents involved in the industrial water pollution abatement as follows:

(a) Perceived damages of affected people

$$\phi(W,E) = \lambda(W)D(E) + (1-\lambda(W))D\left(\bar{E}\right) + V(W) \qquad \text{(B1)}$$

(b) Income to municipal committee

$$M(W,E) = \lambda(W)(s+p)\left(\hat{E} - E\right) + t\left(\hat{E} - E\right) \qquad \text{(B2)}$$

(c) Income to bureaucracy

$$R(W,E) = (b - \lambda(w)p)\left(\hat{E} - E\right) \qquad \text{(B.3)}$$

[19] In the case of an optimal pollution tax or the Pigouvian tax, the liability of a firm is computed as tax rate multiplied by the difference between the actual pollution level and the pollution level with respect to which the marginal damage is zero. However, in the case of the taxes-and-standards method (Baumo and Oates, 1988), we compute the tax liability of a firm as the tax rate multiplied by the difference between the actual and statutory level (level corresponding to pollution standards) of pollution.

(d) Cost to factory

$$C(W,E)=A(E)+(b+s\lambda(W))\left(\hat{E}-E\right)+t\left(\bar{E}-\hat{E}\right) \qquad \text{(B.4)}$$

Net perceived cost to society can be defined as

$$\begin{aligned}\pi(W,E)&=\phi(W,E)+C(W,E)-R(W,E)-M(W,E)\\&=\lambda(W)D(E)+(1-\lambda(W))D\left(\bar{E}\right)+V(W)+A(E)\end{aligned} \qquad \text{(B.5)}$$

Net actual cost to society can be defined as

$$\phi(E,w)=D(E)+V(W)+A(E) \qquad \text{(B.6)}$$

Group I: Affected people and municipal committee with a strategy W and cost function

$$G^{I}=\lambda D(E)+(1-\lambda)D\left(\bar{E}\right)+V(W)-\lambda(s+p)\left(\hat{E}-E\right)-t\left(\bar{E}-\hat{E}\right) \qquad \text{(B7)}$$

Group II: Industry and bureaucracy with a strategy E and cost function

$$G^{2}=A(E)-\lambda(s+p)\left(\hat{E}-E\right)+t\left(\bar{E}-\hat{E}\right) \qquad \text{(B8)}$$

Given penalties and bribe (p, s, b), Group I minimizes G^1 with respect to W given E while Group II minimizes G^2 with respect to E given W. We have:

$$\begin{aligned}&\frac{\delta G^{1}}{\delta W}=\lambda'\left[(s+p)\left(\hat{E}-E\right)-\left(D(E)-D\left(\overline{E}\right)\right)I\right]-V'(W)=0\\&(s+p)\left(\hat{E}-E\right)-\left(D(E)-D\left(\overline{E}\right)\right)=\frac{V'}{\lambda'}\end{aligned} \qquad \text{(B9)}$$

$$\begin{aligned}&\frac{\delta G^{2}}{\delta E}=A'(E)-\lambda(s+p)=0\\&A'(E)=\lambda(s+p)\end{aligned} \qquad \text{(B10)}$$

Equations (B9) and (B10) yield the reaction functions of Groups I and II which are respectively given by (B11) and (B12)

$$W(E), W'(E)<0 \qquad \text{(B11)}$$
$$E(W), E'(W)>0 \qquad \text{(B12)}$$

We define the equilibrium strategies of the two-persons Nash non-cooperative game as

$$W^{*}=W\left(E^{*}\right)$$
and
$$E^{*}=E\left(W^{*}\right)$$

which are given by the intersection of curves depicting the reaction functions of Group I and II in Fig. 4.

Proposition 1: Increasing penalties s and p on industry and bureaucracy have the effects of increasing environmental quality E, given W, and decreasing the time devoted to political activity W, given the environmental quality E. The equilibrium environmental quality of a two-person Nash non-cooperative game increases as either s or p or s and p increase[20].

[20] See Murty (1995) for proof.

TABLES

Table 1: Shadow Prices of Pollutants

(Rs. per tonne)

Industrial Pollutants	Mean	Standard Deviation
SPM	1043	1067
SO2	5867	8706
NOx	11539	21153

Table 2: Physical and Monetary Accounts of Air Pollution for an Average Thermal Power Generating Firm in AP

	SPM	SO2	NOX
Load (Tonnes/yr.)	7836	10488	1668
Shadow Price (Rs.)	1043	5867	11539
Cost of Abatement (Rs. million)	8.173	61.533	19.247

Note: Row 2 of Table shows the data of observed emissions of SPM, NO_X, and SO_2

FIGURES

Figure 1: Pigouvain Tax

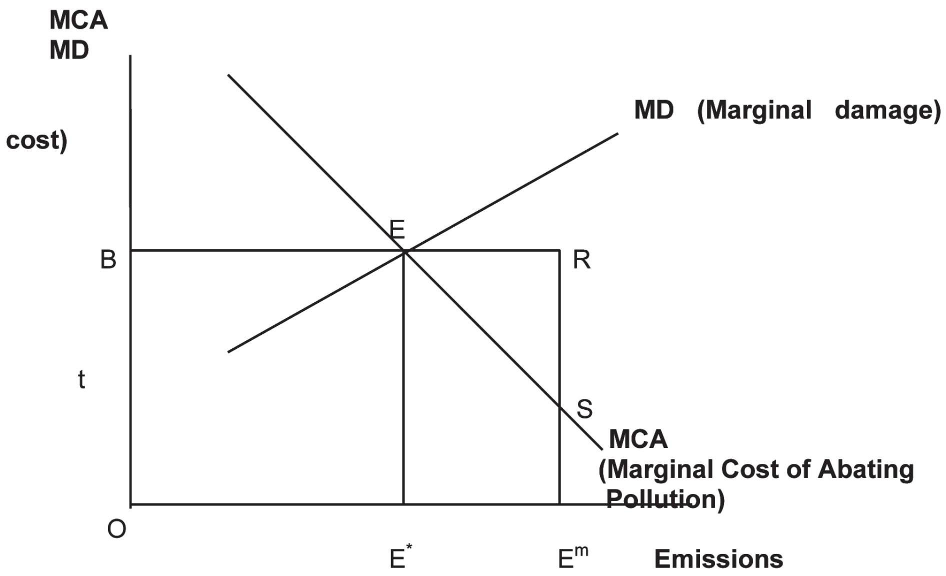


Figure 2: Pollution Tax and Standards

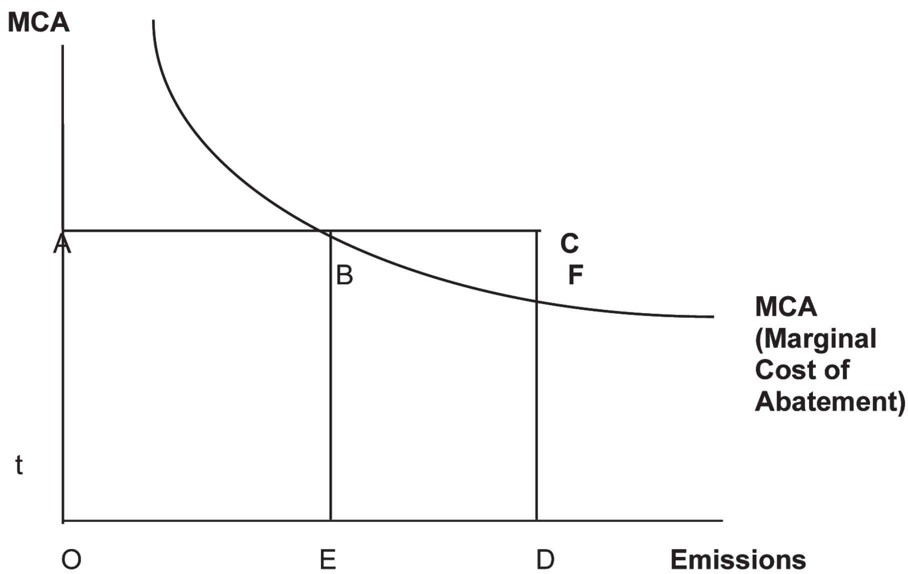


Figure 3: Cosean Bargaining

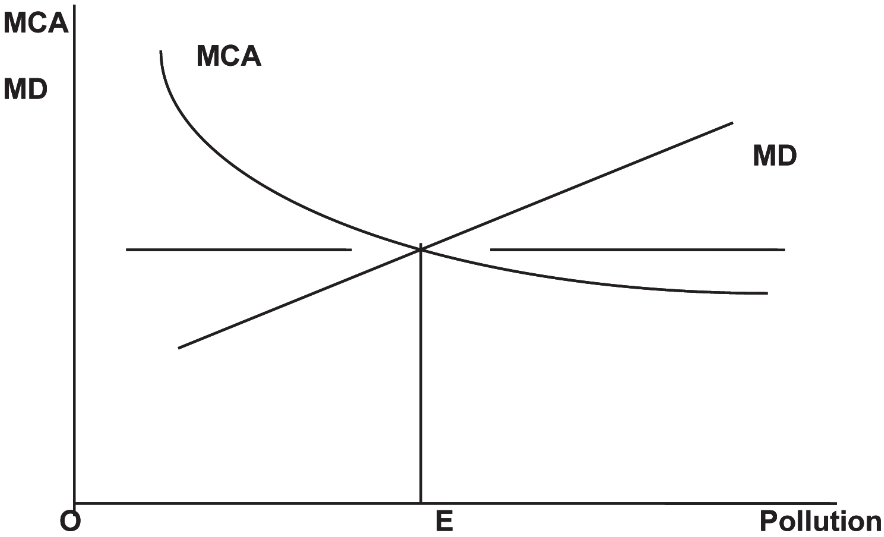


Figure 4: Abatement Function for SPM concentration

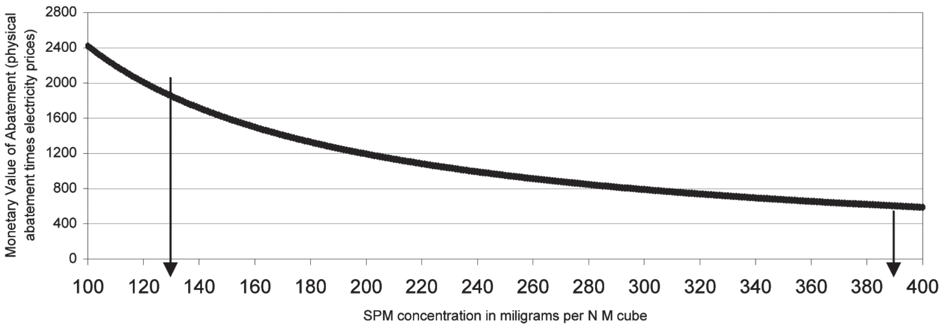


Figure 5: Abatement Function for SO2 Concentration

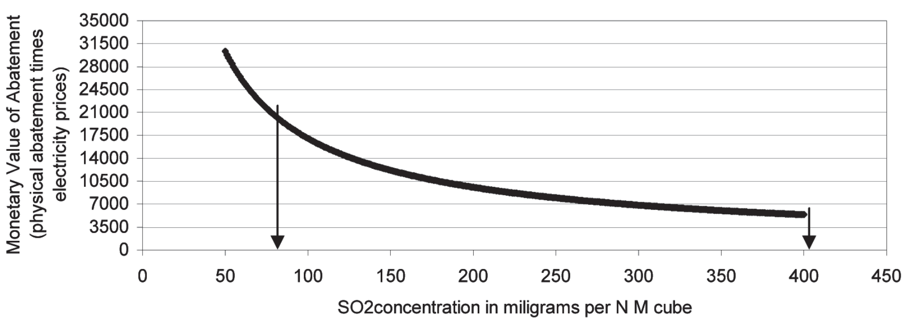


Figure 6: Abatement Function for NOx Concentration

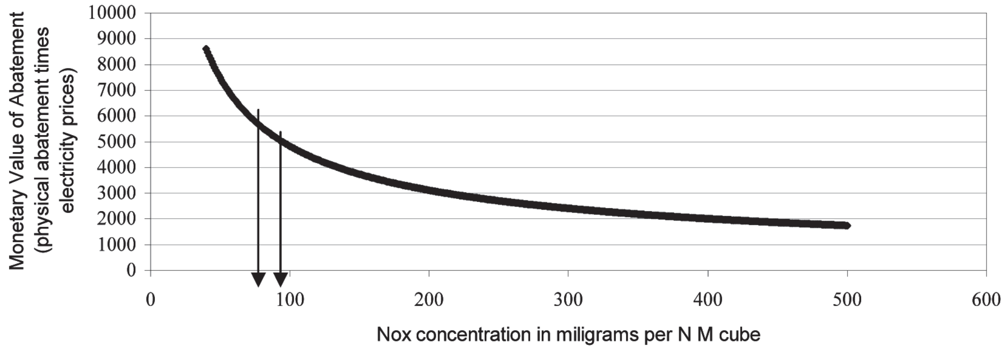
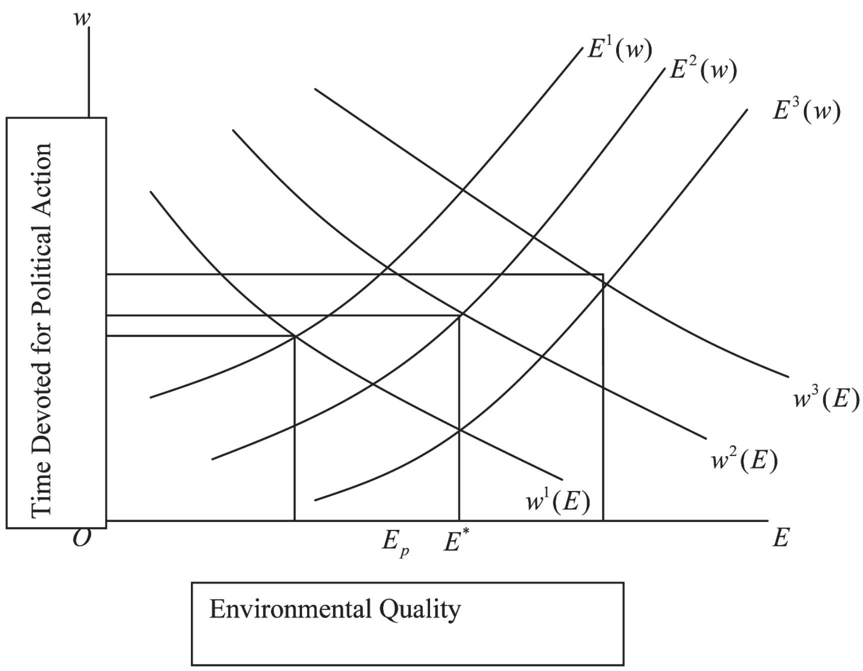


Figure 7: Strategic Behavior of Active Groups in Water Pollution Abatement



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