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THEMATIC ESSAY

Using Economic Instruments to Fix the Liability of Polluters in India: Assessment of the Information Required and Identification of Gaps

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Abstract: The review paper highlights the informational requirements for the effective use of environmental policy instruments to achieve ambient standards of pollution in India. A section on the Integrated Urban Air Pollution Assessment Model is attempted to identify data requirements for, and information gaps associated with, using these instruments. We review the available information and identify informational gaps that thwart the realization of ambient standards of environmental quality. In India, command-and-control instruments are arbitrarily used to assign liability without taking cognizance of economic estimates. The available cost–benefit estimates of air and water pollution, combined with air quality modelling for urban areas and water quality modelling, are essential inputs for using environmental policy instruments to ensure compliance with ambient standards. We discuss how to use economic estimates while designing and using economic instruments such as pollution taxes and pollution permits, in addition to command and control.

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1. INTRODUCTION

The government could use several policy instruments to hold polluters liable for the damage caused to the public through air or water pollution. These are economic instruments such as taxes and subsidies, pollution permits, regulatory instruments of command and control, and penalties. Choosing between these instruments depends both on their efficacy in achieving the target level of emissions and on the relative size of welfare losses that pollutants produce, such as health damages to households (Baumol and Oates 1988). Pollution taxes and pollution permits are price- and quantity-based instruments, respectively. In a market economy with full information, they are the first best or Pareto optimal instruments. However, the available literature shows that if there is incomplete information and uncertainty about the measurement of the benefits and costs of pollution abatement, there will be efficiency losses while employing such taxes and permits (Weitzman 1974). Therefore, there is a clear case for choosing between these instruments especially in the context of using them to reduce carbon emissions for climate change mitigation, etc. Given the limitations concerning the informational requirements for effectively using these instruments, many variants are being used.[4] A common practice is to use one or a combination of these instruments to achieve scientifically determined safe standards for air or water quality.[5] Apart from the direct environmental policy instruments already mentioned, the budgetary policy instruments of commodity taxes could be used to achieve environmental objectives (Sandmo 1975). There could be additional taxes on polluting or carbon-intensive commodities to achieve environmental objectives over and above the taxes levied in lieu of general budgetary policy objectives of equity and efficiency (Murty 1996).

To use environmental policy instruments, the regulator or government requires information about the estimated welfare losses from pollution. Based on this data, regulators can better design instruments that ensure that polluters face liabilities for the welfare losses from pollution.

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[4] See Baumol and Oates (1988) for a theoretical discussion of pollution taxes and permits. Murty (2010) provides a less technical discussion of these instruments.

[5] These are known as pollution tax, pollution permit, and command-and-control standards, depending upon the prime regulatory instrument used. See Sterner (2003) for a discussion on the practical use of these instruments.

In environmental economics, estimates of welfare losses from air and water pollution can be either benefit-based or cost-based. Benefit-based estimates account for health damages and loss of public environmental services as a result of pollution. Cost-based estimates account for the costs that the polluter avoids or saves by doing nothing to reduce pollution.[6] Pollution taxes and permits incentivize polluters to use the following cost-minimizing production and abatement technologies: end-of-pipe treatment technologies, production process changes, input changes, changes in the quality of products, etc. However, in India, only command-and-control and penalty instruments have been used. These instruments are inefficient in that polluters have no incentive to minimize their abatement costs. Pollution taxes and permits are ideal, efficient instruments because they minimize abatement costs by mandating a switch to cleaner technologies. To use these instruments, the regulator requires detailed estimates of abatement costs and potential damages and information on air and water quality modelling.

There have been several central and state legislations to ensure environmental protection in India.[7] They provide for using the policy instruments described earlier to control air and water pollution and to maintain safe air and water quality standards. Source-specific and ambient pollution standards for particulate matter (PM_{10}), sulphur dioxide (SO_2), nitrous oxide (NO_x), carbon dioxide (CO_2), and other emissions for air pollution, and suspended solids (SS), biological oxygen demand (BOD), and chemical oxygen demand (COD) for water pollution, are fixed by the regulator or government. The Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs) are empowered to use environmental policy instruments to make polluters comply with these

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[6] Benefit-based estimates of welfare losses are made using specially designed valuation methods which are classified as stated and revealed preference methods (Freeman 1993; Mitchell and Carson 1989). Several studies have been conducted in India using these methods, some of which are discussed in this paper. Cost-based estimates of welfare losses are calculated using the methods of theory of production: cost functions, distance functions, and by-production models. Some of these estimates for India are discussed in this paper.

[7] The Indian Parliament has enacted various legislations concurrently with, and as follow-ups of, constitutional amendments to protect and improve the environment. The most important among them are the Wildlife (Protection) Act, 1972; the Water (Prevention and Control of Pollution) Act, 1974; the Water (Prevention and Control of Pollution) Cess Act, 1977; the Forest (Conservation) Act, 1980; the Air (Prevention and Control of Pollution) Act, 1981; the Environment (Protection) Act, 1986; the Public Liability Insurance Act, 1991; the National Environment Tribunal Act, 1995; and the National Environment Appellate Authority Act, 1997.

standards. However, thus far, the Indian Government and these agencies have been using only command-and-control regulations.

Command-and-control instruments do not make it clear to what extent polluters are complying with source-specific and ambient standards. Indeed, ambient standards can more accurately assess damages to the public as a result of pollution. Given the higher ambient standards of air pollution in urban areas, there is a permissible pollution load that needs to be achieved to realize them. The pollution load compatible with ambient standards can be obtained by considering source-specific pollution standards in terms of volume, level of activity, the scale of production, and the abatement technologies the polluter uses. The pollution load in an urban area depends on the amount of pollution emitted by each polluter and the number of polluters; this requires that source-specific standards be dynamic. Information on air quality modelling[8] is essential for fixing source-specific standards that are compatible with ambient ones and for using economic instruments.

In the following sections, we discuss informational requirements for using regulatory instruments to control air and water pollution in India. In Section 2, we provide a brief description of the Integrated Urban Air Pollution Assessment Model (IUAPAM), which could be used to estimate pollution levels in the National Capital Territory (NCT) of Delhi. In Section 3, we review the information available in a number of research studies done in India that estimate welfare losses from air and water pollution. In Section 4, we describe the command-and-control regulations currently used in India and how best the estimates of welfare losses can be used. In Section 5, we discuss data requirements and gaps for using taxes and permits to control air pollution in India. In Section 6, we consider methods for fixing liability for water pollution in India. Finally, in Section 7, we present a way forward, highlighting issues of immediate concern to environmental policy in India.

2. INTEGRATED URBAN AIR POLLUTION ASSESSMENT MODEL IUAPAM

The IUAPAM constitutes the following:

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[8] See Section 2 for a discussion on air quality modelling and Baumol and Oates (1988) for a theoretical discussion on air quality modelling in the context of using pollution permits to reduce air pollution in urban areas. It explains that ambient pollution in urban areas comes from different sources. Therefore, the effect of a certain source on ambient pollution depends upon wind direction, meteorological conditions, distance, etc.

(a) Air quality modelling for urban areas

(b) Assessment of benefits and costs of air pollution reduction

(c) Exploration of strategies to reduce air pollution

The information in the IUAPAM helps with designing emissions reduction strategies and judging their efficacy in determining the impacts on cost, air quality, and health. Given the achieved air quality with a given abatement strategy, the model helps to estimate health damages avoided to populations exposed to air pollution.

Consider a more inclusive method of measuring air quality in an urban area in terms of pollution concentration at many receptor points (N) (Baumal and Oates 1988). Identify the number of sources contributing to pollution (M) at each receptor point. The contribution of a source to the pollution at a given receptor point depends upon its distance from the receptor point and prevailing meteorological conditions in the urban area. Let

e_i: $i = 1,2 \ldots M$, quantity of pollution at source i

q_j: j 1, 2 …---N, air quality or pollution concentration at receptor point j

d_{ij}: contribution of one unit of pollution from source i to pollution concentration at receptor point j

The air quality or pollution concentration at receptor point j, q_j, is given as

$$q_j = \sum_{i=1}^{M} d_{ij} e_i$$

There are $M \times N$ air quality diffusion coefficients (d_{ij}) in the model forming a $M \times N$ matrix.

For practical purposes, the air quality at each receptor point could be an annual average, and the relationship between the pollution at a source and the air quality at a receptor point may be linear. Developing a full matrix with information about diffusion coefficients may not be practical. A practical approach could involve dividing a big urban area into a small number of manageable zones, with a receptor point in each zone to measure air quality. In each zone, it could be assumed that the contribution of one unit (tonne) of pollution in the region to the pollution concentration at the receptor point is the same irrespective of the source of pollution. If the city is divided into S number of zones, the observed air quality in s^{th} zone is given as

$$q_s = d_s \times e_s,\ s = 1,2,,\ldots S$$

where e_s is the total quantity of pollution from all sources in region s, and d_s is the contribution of one unit of pollution to the pollution concentration in region s, which is assumed to be constant. Pollution concentration q_s increases with the pollution load given the diffusion coefficient d_s in a given region. In a scenario without regulations, the pollution concentration for the s^{th} region has to be reduced from q_s to q^*, where q^* represents the safe urban air quality standard, approved by the World Health Organization (WHO). Therefore, the pollution load that has to be reduced in the s^{th} region to comply with the WHO air quality standard could be obtained as

$$\Delta e_s = (q_s - q^*)/d_s$$

Using the information from this model about the pollution load reduction required (Δe_s), and the consequent improvement of air quality from the current level q_s to WHO standards q^*, the loss of well-being from air pollution in an urban region can be estimated. The estimates of the cost-based and benefit-based shadow prices of air pollution discussed in this paper could be used along with air quality modelling information for estimating the loss of well-being. The cost-based shadow price (p_c) is the cost to industry for reducing a tonne of PM_{10} emissions and the benefit-based shadow price (p_b) is described as the reduction in health damages avoided by urban households per unit of reduction in pollution concentration (signifying a unit increase in ambient air quality). The cost-based welfare losses (ΔC) and benefit-based welfare losses (ΔB) from urban air pollution could be obtained as

$$\Delta C = p_c \Delta e_s$$

$$\Delta B = p_b (q_s - q^*)$$

The information from this model could be used to design regulatory instruments of command and control; the economic instruments of pollution taxes and permits to deal with point source pollution; and subsidies and incentives for polluters to use appropriate production technologies to reduce pollution from non-point sources to realize the safe WHO air quality standard q^* in a given region. The required reduction in emissions amounting to Δe_s could be realized using any of these instruments. However, taxes and permits can achieve this required reduction at minimal cost, while command-and-control regulations are much more expensive.

To use command-and-control regulations, the regulator can determine the percentage by which the observed pollution load (q_s/d_s) exceeds the pollution load permitted by the WHO standard (q^*/d_s) in the region. Then, the regulator could make it mandatory for each polluter to reduce their pollution by the required percentage points and, failing to do so, face penalties or closure.

The regulator can use cap-and-trade regulations to reduce the pollution load to the permissible level or the WHO standard. Initially, the allowable pollution load (permits) could be distributed among polluters based on their historically observed pollution levels. Since a tonne of pollution, irrespective of its source, contributes the same amount (d_s) to the ambient pollution concentration in the region, polluters could trade on a one-to-one basis. Trade between low- and high-abatement cost polluters could help reduce pollution to the permissible level in the region at the least cost.

The model could be considered for the National Capital Region (NCR), which consists of four regions: National Capital Territory (NCT) of Delhi, some districts in Haryana, some districts in Uttar Pradesh, and some districts in Rajasthan. The IUAPAM could be developed on the lines discussed above and used in the NCT, especially to reduce particulate matter emissions. The NCT Planning Board constituted under the NCT Planning Board Act, 1985, could coordinate between the governments of Delhi, Haryana, Uttar Pradesh, and Rajasthan for this purpose. An interdisciplinary group of experts drawn from the CPCB and concerned SPCBs, research institutes, and universities could be created to develop and implement this model in the NCT.

3. SOME AVAILABLE ESTIMATES OF THE SHADOW PRICES OF AIR AND WATER POLLUTION FOR INDIA

Several studies have been done in India that provide estimates of welfare losses from air and water pollution. There are also many studies that offer estimated costs of air pollution and water pollution abatement. Further, there are several scholarly studies that provide economic estimates of damages due to air and water pollution.

Murty, Kumar, and Dhavala (2007) use the generalized directional distance functions methodology to estimate the shadow prices of SPM, SO_2, and NO_x using data from five coal-fired thermal power–generating plants belonging to Andhra Pradesh Power Generation Corporation

(APGENCO).[9] This study uses panel data containing 480 observations of electricity produced, air pollutants generated (SPM, SO_2, and NO_x), and coal and other inputs that the five electricity-generating plants employ. In the estimation, the electricity generated is considered a good output while the three pollutants SPM, SO_2, and NO_x are considered bad outputs. On reviewing the shadow prices of SPM, SO_2, and NO_x, it is clear that to reduce the emissions of a pollutant by one tonne, a representative firm has to spend INR 12,571, INR 4,956, and INR 17,698 (at 2018 prices), respectively.

Recent studies by Jain and Kumar (2018) and Murty and Nagpal (2019) derive estimates of the shadow prices of CO_2 emissions for the Indian thermal power generation industry. Murty and Nagpal (2019) arrive at two estimates using a by-production model and distance function model with a weak disposability assumption. They use unbalanced panel data from 51 firms for the nine years between 2004–2015. The estimates at 2018 prices using the by-production model and the distance function model are INR 6,806 and INR 6,106, respectively. An effective carbon rate of EUR 30 (INR 2,382.1 at 2018 prices) per tonne was reported in a publication by OECD (2018); this is considered the lowest damage estimate of carbon emissions. Most European countries price carbon at this or a higher rate. It is suggested that to achieve the goals of the Paris Agreement, a carbon rate of USD 40–80 (INR 2,840–5,680 at 2019 prices) by 2020 and USD 50–100 (INR 3,550–7,100 at 2019 prices) by 2030 is required due to the accumulation of CO_2 emissions and the consequent increase in marginal damages over time. These estimates of CO_2 form a range of INR 2,840–7,100 at 2019 prices.

Estimates of the damages resulting from air pollution to households in an urban area, based on current pollution levels above safe ambient standards, and the pollution load to be reduced for each pollutant, have to be obtained to estimate the benefit-based welfare losses. Murty, Gulati, and Banerjee (2004) use the revealed preferences method of hedonic property prices to estimate the environmental benefits of reducing the SPM concentration to the minimal national standards (MINAS) in the megacities of Delhi and Kolkata. The study estimates a typical household's willingness to pay to reduce the level of ambient SPM pollution to the MINAS standards level in Delhi and Kolkata to be INR 46,498 and INR 23,346, respectively, at 2018 prices. By extrapolating these estimates for the entire population of each

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[9] See Murty and Russell (2020) and Chambers and Färe (2020) for recent discussions on the methodologies of by-production models and distance functions for estimating shadow prices of pollutants or bad outputs.

city, the annual benefits come to INR 109,173 million for Delhi and INR 73,719 million for Kolkata, at 2018 prices. It is necessary to conduct similar studies to estimate the benefits of reducing PM_{10}, SO_2, and NO_x to MINAS standards. Additionally, there is an urgent need for air quality modelling information for megacities in India[10] to ensure that polluters are held liable using command-and-control regulations to realize ambient standards.

Several studies have estimated the costs of water pollution abatement—shadow prices or marginal abatement costs (MAC)—in India using the pollution abatement cost function methodology.[11] These studies were conducted during the 1992–1999 period. Murty and Kumar (2002, 2004) estimate the shadow prices of water pollutants for Indian industries using the distance function methodology with the assumption of weak disposability. The data used in these studies are from a survey of water-polluting industries in India done by the Institute of Economic Growth, Delhi. These data reveal the characteristics of the main plants and effluent treatment plants for the years between 1994 and 1995. Estimates of average shadow prices or marginal costs of abatement per tonne of BOD, COD, and SS for Indian water-polluting industries are INR 57,427.92, INR 216,854.94, and INR 71,570.6, respectively, at 2018 prices.

Many studies estimate welfare losses from ambient river water pollution and groundwater pollution in India using environmental valuation methods. For example, Markandya and Murty (2000) attempted a comprehensive evaluation of the Ganga Action Plan (GAP), a project initiated by the Government of India to clean the river and bring the water up to a bathing quality standard. This study estimated the user and nonuser benefits of a clean Ganga using a contingent valuation method. Nonuser benefits were assessed through a survey of urban households in all major cities in India. User benefits, including health benefits, were estimated through a survey of households along the river, covering major urban and rural areas. A typical household's annual willingness to pay to improve the quality of water up to a bathing standard was estimated to be INR 1,501 for non user benefits and INR 1,593 for user benefits, at 2018 prices. The total annual nonuser and user benefits were estimated at INR 16,081 million and 22,044 million, respectively, at 2018 prices.

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[10] See Section 2 for a discussion on air quality modelling.

[11] The studies include those by Gupta, Murty, and Pandey (1989), James and Murty (1996), Mehta, Mundle, and Sankar (1997), Ganguli and Roy (1999), Goldar and Pandey (2001), and Appasamy (2002), among others.

4. USING COMMAND-AND-CONTROL REGULATIONS

There are stack emission standards and ambient standards for air pollution and approaches to ensure the liability of firms depending on whether one considers the former or the latter. The stack emission standards for PM, SO_2, and NO_x in India are 115, 80, and 80 milligrams per cubic metre (Nm^3), respectively. The command-and-control regulations used to estimate the liability of each firm that exceeds the permissible pollution load are based on the pollution load that each firm needs to reduce to achieve industry-wise source-specific standards. This value is the product of the total pollution load in tonnes that the firm has to reduce and the shadow price of the pollutant. The pollution load to be reduced is the difference between the observed concentration of the pollutant and the recommended concentration as per industry-wise source-specific standards. The shadow price of the pollutant is the change in the abatement cost to the firm when one unit of the pollution load is reduced at margin. A review of studies done in India provides estimates of the shadow prices of PM, SO_2, and NO_x at INR 11,651.98, INR 4,592.98, and INR 16,403.52 per tonne, respectively, at 2018 prices.

Polluting firms' immediate compliance with fixed stack emission standards does not necessarily ensure a change in the pollution load in an urban area to ambient standards. Indeed, stack emission standards have to be changed dynamically, with the rising number of polluters, to maintain ambient standards. As discussed in Section 2, information from air quality modelling for urban areas in India could be used to determine permissible pollution loads of PM, SO_2, and NO_x for maintaining ambient air quality standards. Regular monitoring of polluting firms by pollution control boards would reveal the total loads of these three pollutants. The actual pollution load in the city may exceed the estimated pollution load for ambient standards, as explained by the IUAPAM model discussed in Section 2. As per this model, if the load exceeds permissible standards by x%, the regulator using the command-and-control method could mandate an x% reduction of the pollution load of each firm.

Different approaches are needed to determine liability for water pollution depending on the polluter: big factories, small factories in industrial estates, and households in urban areas. Big factories employ in-house treatment technologies and effluent treatment plants, small factories in industrial estates have common effluent treatment plants (CETP), and household-based effluents in urban areas are treated in municipal sewage treatment plants. In the case of a big factory, the quantity of each pollutant (BOD, COD, and SS) to be reduced to comply with source-specific standards could be estimated, given the observed volume of residual water, influent and effluent quality, and standards. Given an estimate of the unit cost of abatement or shadow price for each pollutant, the penalty for the factory could be fixed by pollution control boards using the command-and-control method. Again, factories complying with fixed source-specific water pollution standards for polluters in a river basin does not guarantee ambient river water quality. As the number of polluters around the river basin increase, the pollution load to be reduced to maintain the ambient standards of the river increases. This necessitates dynamic source-specific water pollution standards. Information on water quality modelling similar to the IUAPAM model discussed in Section 2 for the river basin and dynamic source-specific standards for polluters is needed to fix the liability of polluters to uphold ambient river water quality standards.

5. USING MARKET-BASED INSTRUMENTS

The command-and-control regulations described in Section 4 are ineffectual, resulting in firms using cost-inefficient abatement technologies to comply with the standards. It is, therefore, vital to use pollution taxes, permits, and standards. These instruments provide incentives to polluting firms to choose cost-minimizing abatement technologies.

5.1 Pollution Taxes and Standards

This method requires the regulator or government to estimate the pollution abatement cost function that explains the polluters' choices of cost-efficient abatement technologies. Given an estimate of the marginal cost of abatement function and scientifically fixed safe environmental standards, the pollution tax could be determined and levied uniformly on all polluting firms. The pollution tax on a particular pollutant is fixed based on the marginal cost of abatement at the level of pollution corresponding to the standard. The tax imposed makes the liability of a firm higher than the cost of complying with the standards. Therefore, the firm has an incentive to reduce pollution rather than pay a tax.

Some studies[12] offer a method of determining pollution taxes for the thermal power–generating industry to reduce air pollution using the estimated marginal cost of pollution abatement functions for SPM, SO_2, and NO_x. Pollution tax rates are derived for air pollutants for a representative thermal power plant in Andhra Pradesh, using the estimated MAC functions and MINAS stack emission standards. Given the emission standards of 115, 80, and 80 milligrams per $Nm^3$for SPM, SO_2, and NOx,

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[12] See Murty and Gulati (2006) and Murty, Kumar, and Dhavala (2007).

respectively, and the MAC functions for each of these pollutants, the tax rates are estimated at INR 5,524.03, INR 54,000.71, and INR 14,616.69, respectively, at 2018 prices.

5.2 Pollution Permits and Standards

Pollution permit trading is a quantity-based regulation for reducing pollution. Implementing pollution permit trading requires the following: a cap on emissions, distributing emission permits among polluters, and ensuring monitoring and compliance.[13] Examples of successful emissions trading systems are SO_2 trading in the US and CO_2 trading in the European Union. In case of local pollutants like particulate matter, given the ambient pollution standards for a city or a specified region (mg per cubic metre), permissible pollution loads from sources have to be identified and comply with ambient standards. For example, the total pollution load from sources in a region may far exceed the permitted pollution load for ambient standards. The permitted pollution load has to be fixed as a cap. Information about air quality modelling for the region as per the IUAPAM model described in Section 2 is needed to decide the cap on emissions.[14] After deciding the target reduction or cap on emissions, emission permits are created, accounting for tonnes of emissions. These permits are distributed among firms based on their current emissions or through auctions. This, in turn, creates incentives for firms to engage in permit trading, with low-abatement cost firms supplying permits and high-abatement cost firms demanding them. Trading takes place until the marginal cost of abatement is equal among all firms, resulting in cost minimization to achieve target reductions. The success of the permit trading system depends on the regulator monitoring the actions of firms and, if necessary, resetting the cap or target reductions over time. Given that particulate matter emissions are the main cause of concern in urban regions of India, pollution control boards and the government could design and implement permit trading systems to deal with this problem. At present, no country in the world uses cap-and-trade regulation to deal with particulate matter emissions. Historically, this regulation is used in developed countries to deal with SO_2 and CO_2 emissions.[15] In India, there are currently two cap-and-trade schemes: the renewable energy certificates scheme, and the Bureau of Energy Efficiency's (BEE) Perform, Achieve, Trade (PAT) scheme. In addition, there was a study conducted in India to estimate the

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[13] See Duflo, Pande, Greenstone, and Ryan (2010).

[14] See Section 2 for details.

[15] Sulphur dioxide (SO_2) emissions in the US and carbon dioxide (CO_2) emissions in the European Union.

cost-effectiveness of a cap-and-trade programme for intra-firm trade to control particulate matter emissions.[16]

Recently, the Gujarat Pollution Control Board (GPCB) launched a novel cap-and-trade regulation for particulate pollution in Surat.[17] Those who are planning and executing this scheme observed that the most challenging problem was to get all the necessary information about particulate matter emissions from different sources in the region. First, this involved the development of protocols for the continuous monitoring of particulate matter coming from stacks and, second, the installation of a continuous emissions monitors system (CEMS). The CEMS constitutes a network of sensors installed at industries that sends live readings of stack pollution. The Indian Government has made it mandatory for 17 highly polluting sectors (such as pulp and paper, distilleries, sugar, tanneries, power plants, and iron and steel) to install CEMS. However, the study points out that the challenge is in getting the CEMS to produce reliable information, for which the GPCB has been making all possible monitoring efforts. Continuous monitoring by GPCB is necessary so that the CEMS is calibrated to accurately detect pollution in stack emissions.

5.3 Economic Instruments to Control CO_2 Emissions

Greenhouse gas emissions have both domestic externality effects (health damage) and global externality effects (climate change). Some specific institutional arrangements are required to use taxes and permit instruments to deal with these externalities. The literature shows that the optimal tax for a carbon-intensive commodity in a country can be broken down into revenue tax, local air pollution tax, and international carbon tax (Murty 1996). There are many possible institutional alternatives for international agreements to tax carbon-intensive commodities to control local and global environmental pollution. Harmonization of domestic taxes on carbon-intensive commodities is one such option. However, such an arrangement could not result in optimal carbon taxes to reduce carbon emissions to the level of the global optimum. Additionally, this arrangement could provide incentives to countries that are party to the agreement to freeride (Hoel 1991a, 1991b). Research shows that a uniform international tax on carbon

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[16] See Rita Pandey (2004).

[17] The Gujarat Pollution Control Board (GPCB), in collaboration with the Energy Policy Institute of the University of Chicago (EPIC-India), the Abdul Latif Jameel Poverty Action Lab (J-PAL South Asia), and the Evidence for Policy Design at Harvard University (EPoD India), has been experimenting since 2011 on using emissions trading regulations for particulate matter emissions in Surat, Gujarat.

emissions, agreed to by all member countries, may help reduce emissions to a global optimum.

There is a clear choice between a carbon tax and carbon permits instruments in the context of using them to reduce carbon emissions or climate change mitigation by member countries. Weitzman (1974) shows that if there is uncertainty about the benefits and costs of pollution abatement, there will be efficiency losses in the execution of tax and permit instruments. This is a likely hypothetical scenario that a regulator, say the World Government in this case, has to encounter in making a choice between a carbon tax and carbon permits for climate change mitigation (Stern 2007). To reduce carbon emissions to the global optimum level, member countries need to agree to use either an international carbon tax or a cap-and-trade regime. However, there is no agreement of this type so far among countries in spite of international discussions on climate change mitigation. Instead, through the latest Paris Agreement on climate change, many member countries have agreed to nationally determined emissions reductions; India is party to this agreement.[18]

India has to consider using various domestic policies: taxes on carbon-intensive commodities, subsidies for non-conventional energy sources (solar, wind, and hydropower), a uniform national carbon tax, and carbon permit–trading among polluters (trading between industries using fossil fuels, trading between Indian states, etc.). Given that India does not yet use the economic instruments of taxes and permits to deal with local pollution problems, it could use the budgetary policy instruments of commodity taxes and subsidies and even the inefficient regulatory instrument of command and control to reduce carbon emissions. The liability of polluters for CO_2 emissions could be fixed using command-and-control regulations, given the estimate of the shadow price of CO_2 emissions (INR 6,000 per tonne) reported earlier.

5.4 Fixing the Liability for Non-point Sources of Air Pollution

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[18] At the UN Framework Convention on Climate Change in 2015, the parties communicated their intended nationally determined contributions for greenhouse gas reductions. India committed by 2030 (a) to reduce greenhouse gas emissions intensity by 33–35% below the 2005 level, (b) to realize 40% of India's power capacity from non-fossil fuel sources, and c) to create an additional carbon sink of 2.5–3 billion tonnes of CO_2 equivalent through additional forest and tree cover. However, it has to be noted that the estimated aggregate greenhouse gas emissions levels in 2025 and 2030, based on the intended nationally determined contributions by all parties, do not fall within the least-cost 2°C scenarios. A much greater emissions reduction effort will be required to hold the increase in the global average temperature to below 2°C above pre-industrial levels.

Air pollution generated by road transport is a non-point source of pollution; hence, it becomes difficult to assign liability to a single major polluter and to charge a pollution tax. A study by Pandey and Bharadwaj (2004) describes various policy options that address taxes, fuel choices, and vehicular technologies to control vehicular pollution in India. Murty and Gulati (2006) and Murty, Dhaval, Ghosh, and Singh (2006) discuss a method for assigning pollution abatement liability to road vehicles. In these studies, the pollution abatement cost for various categories of vehicles is estimated as the sum of the cost of switching to prescribed vehicular technologies and using better fuels to comply with the stipulated emission norms.

The high degree of correlation among the emission variables recorded in this study indicates that the transition from one emission control vehicular technology to another simultaneously ensures the reduction of emissions from all pollutants. The annual cost of abatement for a passenger car is estimated by taking the maximum of the abatement cost values for all emissions, i.e., for CO_2, NO_x, and HC (Hydro Carbon). The pollution emissions standards for the road sector adopted in India correspond to Euro norms, which vary with the type of vehicle. Subsequently, there exists a variation in vehicular technologies and fuel quality according to the different stages of the Euro norms, i.e., Euro I, II, III, IV, V, and VI.

The study estimates the vehicle-wise pollution abatement cost by adding the cost of upgrading vehicular technologies and of using better quality fuel to conform to the prescribed emissions norms, as shown in Table 1. For instance, the annual cost of abating pollution for a passenger car following Euro III norms can be approximated to INR 15,315 (INR 11,317 for the technology + INR 3,998 for fuel), at 2018 prices. Therefore, regulators or the government could impose liability on vehicle owners for not following the prescribed norms (Euro V or VI at present) using this method.

Table 1: Estimates of the cost per vehicle for changing from Pre-Euro to Euro 3 emissions norms (INR at 2018 prices)

Vehicle	**Change in Technology**	**Fuel Cost**	**Total Cost**
Car	11,317	3,998	15,315
Bus	36,664	20,478	57,142
Truck	36,664	21,349	58,013
Two-wheeler	9,847	1,736	11,583
Three-wheeler	12,448	2,194	14,642

Source: Murty and Gulati (2006)

6. FIXING THE LIABILITY OF POLLUTERS FOR WATER POLLUTION

Water-polluting firms in India are required to meet these water quality standards set by the CPCB: 35mg/L for BOD, 250mg/L for COD, and 100mg/L for SSP. Using the tax standard method, a pollution tax could be levied given estimates of the marginal cost of abatement for water-polluting industries in India and source-specific standards for each pollutant. As pointed out in Section 3, numerous studies in India have estimated the marginal cost of water pollution abatement for different industries. For example, a study by Mehta, Mundle, and Sankar (1994) recommends that the MAC for relatively high-cost producers should serve as the basis for setting charges/taxes to ensure that producers find it cheaper to abate than to pollute. In this study, the authors recommend four options for experimentation by policymakers: (i) abatement charges with the government undertaking clean up; (ii) abatement charges with clean up contracted to organizations through competitive bidding; (iii) a tax proportional to the excess pollution for firms violating standards and subsidies for those exceeding the prescribed abatement standards; and (iv) a private permit trading system.

This study estimates the MAC function for water pollutants in the pulp and paper industry in India. It uses the abatement cost as a function of the quantity of treated water and pollution concentrations in the influent and effluent. This function estimates the marginal cost in INR per 100 gm reduction in the effluent BOD. The average marginal cost per 100 gm of BOD to achieve the MINAS level of BOD (50 mg/L) is estimated to be INR 10.69, at 2018 prices. MAC functions can be used to estimate the cost of a reduction in the effluent for a given level of influent and wastewater. Given the MINAS standards for BOD and the estimated MAC function, the pollution control authority could set its charges at INR 6.33 per 100 gm of extra BOD, at 2018 prices.

A municipal sewage treatment plant in an urban area receives effluents from households and untreated effluents from industries. The municipality charges households in the form of a water pollution tax or cess as part of the price of the municipal water supply. Given that pollution control boards collect penalties or fees from industries that do not comply with standards, they have to compensate the municipality for treating industrial and household effluents.

In the case of river pollution, studies by Markandya and Murty (2000, 2004) consider several different mechanisms for financing the Ganga Action Plan (GAP) of the Government of India for cleaning the Ganga in a sustainable manner. They are (i) a polluter pays principle, (ii) a user pays principle (with government involvement), (iii) a user pays principle (without government involvement), and (iv) funding from the general tax system. Under the polluter pays principle, a water charge per KL is collected as a tax or as a part of a water tariff on all industrial effluents. The user pays principle with government involvement would mean a tax on all beneficiaries. This study estimates the annual willingness of a typical urban household to pay for ensuring bathing quality of the river water at INR 1,506 for non user benefits and INR 1,599 for user benefits, at 2018 prices. The total annual nonuser and user benefits are estimated at INR 16,130 million and INR 22,111 million, respectively, at 2018 prices. Given that a typical household in India is willing to pay INR 3,104 annually at 2018 prices for bathing quality river water, a river cleaning tax of this amount for each household could be a feasible way to raise money to keep the river clean.

7. A WAY FORWARD

In India, the failure to control air and water pollution is attributable to the arbitrary use of command-and-control regulations for controlling industrial pollution and the use of incorrect approaches to deal with non-point sources of pollution like in the transport sector in urban areas. Policy initiatives by the Indian Government have not taken into account economic instruments such as pollution taxes and pollution permits.

As discussed in this paper, apart from the information in the environmental valuation studies, air quality and water quality modelling is essential to effectively use pollution taxes, pollution permits, and command-and-control instruments. The IUAPAM could potentially be used to control air pollution in the National Capital Territory (NCT) of Delhi. There is an urgent need for government and non-governmental initiatives to develop information systems for all major urban areas and river systems in India. Without such information, policy instruments, including command and control, become ineffective, as in the current reality in India.

More studies have to be done in major urban areas in India to estimate health and other welfare losses for households and industry-specific pollution abatement costs due to air and water pollution. These estimates, along with an estimate of the pollution dispersion coefficient matrix, become important inputs for using IUAPAM to determine the liability of polluters in an urban region.

Controlling pollution from non-point sources of pollution like road transport vehicles and water pollution from agriculture requires designing specific approaches. One approach to fixing the liability of vehicular traffic is discussed in this paper. Also, specially designed methods are required to deal with household water pollution in urban areas, taking into account that the influents to sewage treatment plants come from both households and industries.

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REFERENCES

Appasamy, P. 2002. "Environmental Impact of Industrial Effluents in Noyyal River Basin." Unpublished report, Madras School of Economics.

Baumol, WJ and Wallace E Oates. 1988. *The Theory of Environmental Policy*. Cambridge University Press. https://doi.org/10.1017/CBO9781139173513 .

Chambers, Robert G, and Rolf Färe. 2020. "Distance Functions in Production Economics." In *Handbook of Production Economics*, edited by Subhash C Ray, Robert G Chambers, and Subal C Kumbhakar, 1–53. Singapore: Springer. https://doi.org/10.1007/978-981-10-3450-3_14-1 .

Chatterjee, Sushmita, Kishore K Dhavala, and MN Murty. 2007. "Estimating Cost of Air Pollution Abatement for Road Transport in India: Case Studies of Andhra Pradesh and Himachal Pradesh." *Economic &Political Weekly* 42 (36): 3662–3668.

Duflo, Esther, Rohini Pande, Michael Greenstone, and Nicholas Ryan. 2010. "Towards an Emissions Trading Scheme for Air Pollutants in India: A Concept Note." Working Papers No. 3178*, eSocialSciences.*

Freeman, A Myrick, III. 1993. "The Measurement of Environmental and Resource Values: Theory and Methods", Washington DC: Resources for the Future.

Ganguli, S, and Joyashree Roy. 1999. "Water Pollution Abatement Cost and Tax in the Paper Industry." In *Environmental Economics in India: Concepts and Problems*, edited by Gautam Gupta and Joyashree Roy. Allied Publishers Ltd.

Garaga, Rajyalakshmi, Shovan Kumar Sahu, and Sri Harsha Kota. 2018. "A Review of Air Quality Modeling Studies in India: Local and Regional Scale." *Current Pollution Reports* 4(2): 59–73. https://doi.org/10.1007/s40726-018-0081-0.

Goldar, Bishwanath, and Rita Pandey. 2001. "Water Pricing and Abatement of Industrial Water Pollution: Study of Distilleries in India." *Environmental Economics and Policy Studies* 4 (2): 95–113. https://doi.org/10.1007/bf03353918.

Gupta, DB, MN Murty, and Rita Pandey. 1989. "Water Conservation and Pollution

Abatement in Indian Industry: A Study of Water Tariff." New Delhi: National Institute of Public Finance and Policy.

Hoel, Michael. 1991a. "Global Environmental Problems: The Effects of Unilateral Actions Taken by One Country." *Journal of Environmental Economics and Management* 20(1): 55–70. https://doi.org/10.4324/9781315202310-10.

Hoel, Michael. 1991b. "Carbon Taxes: An International Tax or Harmonized Domestic Taxes?" *CICERO Working Papers.*

Jain, Rakesh Kumar, and Surender Kumar. 2018. "Shadow Price of CO_2 Emissions in Indian Thermal Power Sector." *Environmental Economics and Policy Studies* 20 (4): 879–902. https://doi.org/10.1007/s10018-018-0218-9.

James, AJ, and MN Murty. 1996. "Water Pollution Abatement: A Taxes-and-standards Approach for Indian Industry." In *Economics of Industrial Pollution: Indian Experience*, edited by MN Murty and Smita Misra. New Delhi: Oxford University Press.

Markandya, Anil and MN Murty. 2000. *Cleaning Up the Ganges: The Cost Benefit Analysis of Ganga Action Plan.* New Delhi: Oxford University Press.

Markandya, Anil, and MN Murty. 2004. "Cost–Benefit Analysis of Cleaning the Ganges: Some Emerging Environment and Development Issues." *Environment and Development Economics* 9(1): 61–81. https://doi.org/10.1017/s1355770x03001013.

Mehta, Shekhar, Sudipto Mundle, and Ulaganathan Sankar. 1997. *Controlling Pollution: Incentives and Regulations*. Thousand Oaks, CA: Sage Publications.

Mitchell, Robert Cameron, and Richard T Carson. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Washington, DC: Resources for the Future.

Murty, MN. 1996. "Fiscal Federalism Approach for Controlling Global Environmental Pollution." *Environmental and Resource Economics* 8(4): 449–459. https://doi.org/10.1007/bf00357413.

Murty, MN, and Surender Kumar. 2002. "Measuring the Cost of Environmentally Sustainable Industrial Development in India: A Distance Function Approach." *Environment and Development Economics* 7(3): 467–486. https://doi.org/10.1017/s1355770x02000281.

Murty, MN, and Surender Kumar. 2004. *Environmental and Economic Accounting for Industry*. New York: Oxford University Press.

Murty, MN, SC Gulati, and Avishek Banerjee. 2004. "Benefits from Reduced Air Pollution in the Cities of Delhi and Kolkata in India Using Hedonic Property Prices Model." In *Environmental Valuation in South* Asia, edited by AK Enamul Haque, MN Murty, and Priya Shyamsundar, 380–411. New Delhi: Cambridge University Press.

Murty, MN, Kishore Kumar Dhavala, Meenakshi Ghosh, and Rashmi Singh. 2006. "Social Cost–Benefit Analysis of Delhi Metro." New Delhi: Institute of Economic Growth.

Murty, MN, and SC Gulati. 2006. "Natural Resource Accounts of Air and Water Pollution: Case Studies of Andhra Pradesh and Himachal Pradesh States of India." New Delhi: Institute of Economic Growth.

Murty, MN, Surender Kumar, and Kishore Kumar Dhavala. 2007. "Measuring Environmental Efficiency of Industry: A Case Study of Thermal Power Generation in India." *Environmental and Resource Economics* 38 (1): 31–50. https://doi.org/10.1007/s10640-006-9055-6.

Murty, MN. 2009. *Environment, Sustainable Development and Well-Being: Taxation, Incentives and Valuation.* New Delhi: Oxford University Press.

Murty, MN. 2010. "Designing Economic Instruments and Participatory Institutions for Environmental Management in India." Working Paper No. 48–10, South Asian Network for Development and Environmental Economics.

Murty, MN, Haripriya Gundimeda, Sukanya Das., and Kavita Sardana. 2019. "Meta-analysis for Environmental Damage Assessment." New Delhi: TERI School of Advanced Studies.

Murty, Sushama, and Resham Nagpal. 2019. "Measuring Output-based Technical Efficiency of Indian Coal-based Thermal Power Plants: A By-production Approach." *Indian Growth and Development Review* 13(1): 175–206. https://doi.org/10.1007/s10640-006-9055-6.

Murty, Sushama, and R Robert Russell. 2020. "Bad Outputs." In *Handbook of Production Economics*, edited by Subhash C Ray, Robert G Chambers, and Subal C Kumbhakar, 1–53. Singapore: Springer. https://doi.org/10.1007/978-981-10-3450-3_3-1 .

OECD. 2018. "Carbon Pricing in 2015 – Detailed Analysis." In *Effective Carbon Rates 2018: Pricing Carbon Emissions Through Taxes and Emissions Trading*. Paris: OECD Publishing. https://doi.org/10.1787/9789264305304-5-en

Pandey, Rita. 2004. "Economic Policy Instruments for Controlling Vehicular Air Pollution." *Environment and Development Economics* 9(1): 47–59. https://doi.org/10.1017/s1355770x03001025.

Pandey, Rita, and Geetesh Bhardwaj. 2004. "Comparing the Cost Effectiveness of Market-based Policy Instruments Versus Regulation: The Case of Emission Trading in an Integrated Steel Plant in India." *Environment and Development Economics* 9(1): 107–122. https://doi.org/10.1017/s1355770x03001104.

Sandmo, Agnar. 1975. "Optimal Taxation in the Presence of Externalities." *The Swedish Journal of Economics* 77(1): 86–98. https://doi.org/10.2307/3439329.

Stern, Nicholas, and Nicholas Herbert Stern. 2007. *The Economics of Climate Change: The Stern Review.* Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511817434 .

Sterner, Thomas. 2003. *Policy Instruments for Environmental and Natural Resource Management.* New York: Routledge.

Weitzman, Martin L. 1974. "Prices vs. Quantities." *The Review of Economic Studies* 41(4): 477–491. https://doi.org/10.2307/2296698.