Environmental and Economic Accounting for Indian Industry

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Abstract:
This paper attempts the valuation and accounting of industrial pollution in India. It shows that how the estimated shadow prices of a vector of pollutants can be used to design pollutant-specific taxes, and to estimate environmentally corrected GDP for India. Shadow prices of a vector of bad outputs (pollutants) are obtained by estimating the output distance function. The data collected for a large number of polluting firms in India through two surveys, one conducted in 1995 and another in 2000 are used to estimate the output distance function. The estimates of shadow prices show that on an average the cost to the Indian industry for reducing one ton of BOD, COD, and SS are respectively, Rs 18,696, Rs. 45,104 and Rs. 27,044. Large differences in the estimates of firm-specific shadow prices of pollutants reflect the use of inefficient water pollution abatement technologies. The relationships between firm specific shadow prices or marginal costs of abatement of BOD, COD, and SS and the index of compliance (effluent concentration ratio) show that there is an increasing marginal cost of pollution abatement. Using the taxes-standards approach to pollution control, the taxes necessary for making the firms to comply with the national standards of water pollution are estimated. The estimated taxes for making the firms to realize the standards of 35mg/l for BOD, 250mg/l for COD, and 100mg/l for SS are respectively given as Rs. 20,157, Rs. 48,826, and Rs. 21,444 per ton. Physical and monetary accounts are developed for industrial water pollution in India. The estimates of cost of abatement of water pollution currently incurred by the industry and the cost that has to be incurred in a hypothetical scenario of all firms meeting the national standards are made. Also estimates of net pollution loads of the industry and their monetary values are made. The environmentally corrected NNP for industrial water pollution in India can be obtained by deducting the monetary value of net pollution loads from the estimate of conventional NNP for India.

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1. Introduction

It is now known that sustainable industrial development requires the preservation of the environment. Industries create a demand not only for waste receptive services from the environmental media: air, forests, land and water but also for some material inputs supplied by the environmental resources (for example, wood in the paper and pulp industry). Environmental resources can ensure a sustainable supply of these services, if they are preserved at their natural regenerative level or the demand for waste receptive services is equal to the waste assimilative capacity of the environmental resources. Given that the demand for environmental services from various economic activities can exceed the natural sustainable levels of supply at a given time, and if measures are not taken to reduce this excess demand to zero then it is likely that there can be a degradation of environmental resources. The cost of reducing the demand for environmental services to the natural sustainable level of supply is regarded as the cost of sustainable use of environmental resources and in the case of industrial demand for environmental services, it is the cost of sustainable industrial development.

As a part of environmental regulation, a firm faces a supply constraint on environmental services in the form of prescribed standards for the effluent quality. The effluent standards are normally fixed such that the demand for the services of environmental media does not exceed the natural sustainable level of supply. The firm has to spend some of its resources to reduce the pollution loads to meet the effluent quality standards. The firm with a resource constraint will have lesser resources left for the production of its main product after meeting the standards. Therefore, the opportunity cost of meeting these standards is in the form of a reduced output of the firm. If all the firms in the industry meet the standards, the value of the reduced output of firms is the cost of sustainable industrial development. How to estimate this cost for a competitive firm facing the environmental regulation? It has to be estimated by studying the firm's behaviour in the decision-making regarding pollution loads and the choice of pollution abatement technologies. In some of the recent studies, the technology of a polluting firm is modelled on one of the two basic approaches using the conventional methods of the theory of production: (a) Considering effluent as an additional input in the production or profit function, and (b) By including abatement expenditures as an additional input in a cost function. In some studies, the pollution abatement technology is modelled with the assumption that it is non-separable from the technology of the main products while in others it is modelled with the assumption it is separable. In response to environmental regulation, firms may adopt different types of technologies to reduce pollution. Jorgenson and Wilcoxen (1990) identify three different responses of firms. First, the firm may substitute less polluting inputs for more polluting ones. Second, the firm may change the production process to reduce emissions. Third, the firm may invest in pollution-abatement devices. In practice, a firm may adopt a mix of these methods. The first two methods are non-separable with the production processes of main products while the third method is known as end-of-the pipe method.

There are a number of empirical studies beginning with the early eighties that examine the impact of environmental regulation on the economic performance of firms[1]. The ultimate aim of these studies has been to measure the effect of pollution regulation on total factor productivity growth (TFP). Most of these studies are based on production, cost or profit functions, with the pollution variable modelled indirectly using abatement expenditure as one of the inputs. The technology of water or air polluting firms could be described as one of joint production of good and bad outputs, the bad output being the pollution. The assumption of free disposal (a multi-product firm can produce more of one output without reducing the outputs of other goods) that is normally made in the conventional production theory cannot be applied to describe the technologies of polluting firms. Shephard (1970, p.205) noted that:

> ***"...for the future where unwanted outputs of technology are not likely to be freely disposable, it is inadvisable to enforce free disposal of inputs and outputs. Since the production function is a technological statement, all outputs, whether economic goods are wanted or not, should be spanned by the output vector y".***

Also, the conventional studies have implicitly assumed that the firms are operating on the production frontier and that pollution control does not have an impact on production efficiency. However, many recent studies have shown that these assumptions are unlikely to hold in many cases.[2] Finally, the profit or cost functions used to represent production technology require firm specific prices, especially input prices,[3] the reliable data of which is difficult to obtain. As will be shown in this

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[1] See Myers and Nakamura, 1980; Pittman, 1981, 1983; Gollop and Roberts, 1983; Conrad and Morrison, 1989; Jorgenson and Wilcoxen, 1990; Barbara and McConnell, 1990, and Gray and Shadbegian, 1993, 1995.

[2] See Fare et al. 1989; Fare et al. 1993; Hakuni, 1994; Yaisawarng and Klien, 1994;Porter and van der Linde, 1995; Coggin and Swinton, 1996, and Surender Kumar, 1999.

[3] See recent studies on pollution abatement cost functions in India. For example, Mehta et al. 1995; James & Murty 1998; Pandey, 1998, and Smita Misra, 1999.

chapter and the subsequent two chapters, the distance function approach for describing the production technology of a firm will potentially avoid all these problems.

The remaining paper is as follows: Section 2 describes the methodology of the estimation of shadow prices of pollutants. Section 3 provides information about the data used in the estimation of shadow prices and the specification of output distance function to be estimated. Section 4 presents the estimates of shadow prices of bad outputs. Section 5 discusses the design of pollution taxes using the shadow prices of bad outputs. Section 6 presents the physical and monetary accounts of industrial pollution in India and provides estimates of the environmentally corrected NNP of India for industrial pollution. Monetary accounts are developed using the estimated shadow prices of bad outputs. Finally, Section 7 provides conclusions.

2. Methodology

The conventional production function defines the maximum output that can be produced from an exogenously given input vector while the cost function defines the minimum cost to produce the exogenously given output. The output and input distance functions generalise these notions to a multi-output case. The output distance function describes "how far" an output vector is from the boundary of the representative output set, given the fixed input vector. The input distance function shows how far is the input vector from the input vector corresponding to the least cost for producing a given vector of outputs.

Suppose that a firm employs a vector of inputs $x \in \Re^N_+$ to produce a vector of outputs $y \in \Re^M_+$, $\Re^N_+$, $\Re^M_+$, 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) is the input requirement set for a given output vector y. Now the technology set is defined as:

$$T = \{ (y,x) \in \Re^{M+N}_+ \ y \in P(x), x \in L(y)\}. \qquad (1)$$

The output distance function is defined as,

$$D_O(x,y) = \min\{ \theta > 0 : (y/\theta) \in P(x)\} \ \forall x \in \Re^N_+. \qquad (2)$$

Equation (2) characterises the output possibility set by the maximum equi-proportional expansion of all outputs consistent with the technology set (1).

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

That means, we can reduce some outputs given the other outputs or without reducing them. This assumption may exclude important production processes, such as undesirable outputs. For example, in the case of water pollution, Bio Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Suspended Solids (SS) are regulated and the firm cannot freely dispose of them. The assumption of weak disposability is relevant to describe such production processes. The assumption of weak disposability implies,

if $y \in P(x)$ and $0 \le \theta \le 1 \Rightarrow \theta y \in P(x)$.

That means, 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 in computing shadow prices using the (input) distance function and non-parametric linear programming methods. Fare et al. (1993) present the first study deriving the shadow prices of undesirable outputs using the output distance function.

The derivation of absolute shadow prices for bad outputs using the distance function requires an assumption that one observed output price is a 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[4],

$$(r_m^s) = (r_1^0) \bullet \frac{\partial D_0(x,y) / \partial y_m}{\partial D_0(x,y) / \partial y_1}. \qquad (3)$$

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, p. 376). Further, the shadow prices do not require that the plants operate on the production frontier.

3. Translog Output Distance Function and Data

[4] See Fare (1988) for derivation.

In order to estimate the shadow prices of pollutants (bad outputs) for the Indian industry using equation (3), the parameters of output distance function have to be estimated. The translog functional form[5] is chosen for estimating the output distance function for the Indian water and air polluting industries which is given as follows:

$$\ln D_o(x, y) = \alpha_0 + \sum\beta_n \ln x_n + \sum \alpha_m \ln y_m + 1/2\sum \sum \beta_{nn'} (\ln x_n) (\ln x_{n'}) + 1/2 \sum \sum \alpha_{mm'} (\ln y_m) (y_{m'}) + \sum \sum \gamma_{nm} (\ln x_n) (\ln y_m) + \iota_i D_i \quad (4)$$

where x and y are respectively, Nx1 and Mx1 vectors of inputs and outputs, and D_i stands for the dummy variables used for time periods and industry specifications. The data used in this paper is from two surveys of water and air polluting industries in India.[6] The data from these surveys provide information about the characteristics of polluting firms for the years 1994-1995, 1996-1997, 1997-1998, and 1999-2000. It consists of sales value, capital stock, wage bill, material input cost, waste water volume, influent and effluent quality for BOD (Bio Oxygen Demand), COD (Chemical Oxygen Demand) and SS (Suspended Solids), capital stock, wage bill, and fuel and material input cost for a sample of 60 firms for the year 1994-1995 and for a sample of 120 firms for the three years during 1996-1999. Thus the data constitute an unbalanced panel. These firms in the sample belong to tanneries, chemicals, fertilisers, pharmaceuticals, drugs, iron and steel, thermal power, refining and others. For estimating the output distance function, the technology of each water polluting plant is described by joint outputs: sales value (good output) and COD, BOD and SS (bad outputs) and inputs: capital, labour, and fuel and materials. In the case of air polluting industries, the bad outputs considered are SO_2, NO_x and suspended particulate matter (SPM). However, most of the firms in the sample could not provide all the required information about the air pollution.

The water polluting firms in the Indian industry are supposed to meet the standards set for the pollutants (35mg/l for BOD, 250mg/l for COD, and 100mg/l for SSP) by the Central Pollution Control Board. Command and Control regulatory instruments are used to make the firms realise the standards. Most of the firms in the sample have effluent treatment plants and in addition some firms are using process changes in production and input choices to achieve the effluent standards. However, there is a large variation in the degree of compliance among the firms measured in terms of ratio of

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

[6] A Survey of Water Polluting Industries in India, 1996 and A Survey of Water and Air polluting Industires in India, 2000, Institute of Economic Growth, Delhi.

standard to effluent quality. The laxity of formal environmental regulation by the government, use of command and control instruments, and the absence of informal regulation[7] by

Table 1: Descriptive Statistics of Indian Water Polluting Industry

		Mean	Median	Maximum	Minimum	Standard Deviation.
T		1802.008	652.97	26916.46	0.3825	3320.584
M		951.7418	321.217	38516.1	0.515	2717.406
W		1165.321	40.245	349821.8	0.060211	18577.52
KS		2622.139	379.084	74538.09	0.004257	8660.077
VW		1618054	210000	2362500	175	3798211
Influent (conc.)						
BOD		16352.55	650	684375	3.5	76436.27
COD		109910.4	1500	6159375	35	597266.6
SS		158892.7	312	15658500	3.25	1081616
Effluent (conc.)						
BOD		147.2786	30	6390	0.095	540.3057
COD		753.6231	190	32500	10	2925.207
SS		124.7263	63	3500	0.095	382.2771
Influent load						
BOD		26459.308	164.010	2570000	105	164000
COD		177840.962	316.680	40914.048	1.344	5452.796
SS		257096.969	87.500	15658.500	0.105	2086.237
Effluent load						
BOD		238.304	11.288	1311.975	0.002	138.160
COD		1219,402	41.580	9594.375	21..875	1087.005
SS		201.813	14.565	1771.875	0.005	304.602
Pollution load						
as per standard						
BOD		48.541	6.300	708.750	0.005	113.946
COD		404.513	52.500	5906.250	0.044	949.552
SS		161.805	21.000	2362.500	0.017	379.821

Notes:
T: Turnover(Rs.million)
M: Material inputs(Rs. million)
W: Wage-bill(Rs. Million)
K: Capital Stock(Rs. Million)
VW: Waste Water Volume(KL)
BOD Load: Bio-oxygen demand(tons)
COD Load: Chemical oxygen demand(tons)
SS Load: Suspended Solids(tons)

Table 2: Descriptive Statistics of Air Pollution

[7] For empirical evidence about informal regulation by the local communities see Murty et al. (1999) and World Bank, 1999.

	Mean	Median	Maximum	Minimum	Std. Dev.
NO_2	217.5645	17.943	2007.825	0.265	463.57
SO_2	834.7688	143.306	14036.4	2.125	2607.432
SPM	43232.44	2423.081	258635.6	1.354	79696.36

Note: NO_2, SO_2 and SPM are in tons.

the communities in the neighbourhood of the firms can be regarded as factors responsible for large variations in the compliance to the pollution standards by the firms. Tables 1 and 2 provide the descriptive statistics of variables used in the estimation of output distance function in this paper.

4. Estimates of Output Distance Function and Shadow Prices of Bad Outputs

In this section, a linear programming technique is used to estimate the parameters of a deterministic translog output distance function (Aigner and Chu, 1968). This is accomplished by solving the problem,

$$\max \sum [\ln D_o (x , y) - \ln 1], \qquad (5)$$

subject to

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

(ii) $(\partial \ln D_o (x, y))/(\partial \ln y_1) \geq 0$

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

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

(v) $\sum \alpha_m = 1$

$\sum \alpha_{mm'} = \sum \gamma_{nm} = 0$

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

$\beta_{nn'} = \beta_{n'n}$

Here the first output is desirable and the rest of (M-1) outputs are undesirable. The objective function minimises 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 the maximisation of the objective function is done implying the minimisation of 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) imply that the output distance function is non-decreasing in good outputs. In other words they ensure that the desirable outputs have non-negative shadow prices. The constraints in (iii) imply that the output distance function is non-increasing in bad outputs. They restrict the shadow prices of the bad outputs to be non-positive. The constraints in (iv) imply that the output distance function is non-increasing in inputs. The constraints in (v) impose homogeneity of degree +1 in outputs (which also ensures that technology satisfies 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.

Tables 3and 4 provide respectively linear programming estimates of output distance function for the Indian water and air polluting industries. Table 5 provides estimates of industry-specific shadow prices for bad outputs, BOD, COD, and SS based on the parameters of translog distance function estimated using programming approach. Table 6 provides similar estimates for air pollutants. These shadow prices are negative, reflecting desirable output and revenue foregone as a result of reducing the effluent by one unit (ton) per year. For instance, the average shadow price for water polluting Indian industries is Rs. 13,290 for BOD, Rs. 50,623 for COD, and 16,676 for SS per ton at 1996-97 prices. That means the reduction of BOD by one ton reduces Rs. 13,290 worth of production of positive output. There is a significant variation of shadow prices of pollutants across the sample of observations as shown in Table 5. The range of shadow prices for BOD is Rs. 36,000 to Rs. 113 per ton , for COD, it is Rs. 1,74,000 to Rs. 397 per ton, and for SS, it is Rs. 68,000 to Rs. 623. This can be explained by the variation in the degree of compliance as measured by the effluent concentration, and different vintages of capital used by the firms for the production of desirable output and the pollution abatement. The estimates of shadow prices of air pollution reported in Table 6 appear to be very high in comparison to the estimates in the studies made for other countries. Given the poor quality of data obtained about the air pollution for the sample of firms surveyed, these estimates are not reliable.

Table 3: Parameter Estimates of Output Distance Function for all industries with water pollution as bad outputs (Weak Disposability)

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
Constant	-2.839						
Y_1	1.202	X_{22}	-0.162	Y_1X_1	-0.14	D1	0.133
Y_2	-0.007	X_{33}	-0.013	Y_1X_2	0.228	D2	-0.059
Y_3	-0.155	Y_{12}	0.004	Y_1X_3	-0.062	D3	-0.034
Y_4	-0.039	Y_{13}	0.025	Y_2X_1	-0.002	D4	0.109
X_1	0.501	Y_{14}	0.008	Y_2X_2	4.12E-05	D5	-0.134
X_2	-1.355	Y_{23}	-0.006	Y_2X_3	-0.001	D6	-0.195
X_3	-0.083	Y_{24}	0.002	Y_3X_1	-0.002	D7	0.132
Y_{11}	-0.047	Y_{34}	-0.003	Y_3X_2	-0.01	D8	-0.152
Y_{22}	0.002	X_{12}	0.142	Y_3X_3	-0.008	D9	0.088
Y_{33}	0.016	X_{13}	0.078	Y_4X_1	-0.000597	D10	0.182
Y_{44}	0.000555	X_{23}	0.034	Y_4X_2	0.0006466	D11	0.171
X_{11}	-0.06			Y_4X_3	-0.003		

Table 4 Parameter Estimates of Output Distance Function for all industries with air pollution as bad outputs(Weak Disposability)

Parameter	Value	Parameter	Value	Parameter	Value
Constant	3.535	X_{11}	0.252	Y_1X_1	-0.046
Y_1	0.878	X_{22}	0.028	Y_1X_2	0.027
Y_2	0.201	X_{33}	-0.003	Y_1X_3	--0.004
Y_3	-0.079	Y_{12}	0.283	Y_2X_2	-0.125
X_1	-3.004	Y_{13}	-0.284	Y_2X_3	0.063
X_2	-0.505	Y_{23}	-0.356	Y_3X_1	0.437
X_3	0.602	X_{12}	-0.129	Y_3X_2	0.167
Y_{11}	0.004	X_{13}	-0.021	Y_3X_3	-0.088
Y_{22}	0.212	X_{23}	0.005		
Y_{33}	0.141				

Table 5: Descriptive Statistics of Estimates of Shadow Prices of Water Pollution for Indian Industries (Rs. million per ton)

Industry/Pollutant	Mean	S.D.	Minimum	Maximum
Overall				
BOD	0.0132901	0.0060858	0.0001130	0.036
COD	0.0506225	0.0266572	0.0003972	0.174
SS	0.0166764	0.0086278	0.0006226	0.068
Leather				
BOD	0.0107059	0.0036702	0.003	0.016
COD	0.0631765	0.0329322	0.001	0.112
SS	0.0217059	0.0081759	0.007	0.039
Distillery				
BOD	0.0186957	0.0095462	0.003	0.036
COD	0.0451042	0.0397984	0.0003972	0.174
SS	0.0270435	0.0149225	0.008	0.068
Chemicals				
BOD	0.0111818	0.0050299	0.001	0.02
COD	0.0522182	0.0255268	0.005	0.136
SS	0.0130909	0.0051398	0.007	0.028
Sugar				
BOD	0.0122992	0.004085	0.002	0.029
COD	0.0558268	0.0206413	0.003	0.15
SS	0.0167795	0.0075665	0.002	0.05
Paper & Paper Products				

BOD	0.0184694	0.0043498	0.004	0.026
COD	0.0291837	0.0189458	0.001	0.106
SS	0.0184286	0.0057591	0.007	0.035
Fertilizer				
BOD	0.0106	0.0046043	0.002	0.021
COD	0.05585	0.0226792	0.007	0.091
SS	0.01065	0.0055939	0.001	0.019
Drug & Pharmaceutical				
BOD	0.0092813	0.0077071	0.0004143	0.02
COD	0.0638333	0.021599	0.006	0.092
SS	0.0206667	0.008968	0.002	0.029
Petro-Chemicals				
BOD	0.01365	0.0055086	0.006	0.025
COD	0.04175	0.0227269	0.008	0.099
SS	0.0125311	0.007786	0.0006226	0.027
Misc.				
BOD	0.0134458	0.0101472	0.000113	0.036
COD	0.0592667	0.0393146	0.005	0.129
SS	0.012	0.0080356	0.001	0.032

Table 6:Shadow Prices of Air Pollution
(1996-97 prices)

Pollutant	Mean	S.D.	Minimum	Maximum
NO_X	1.8134333	0.6045031	0.054	2.664
SO_2	1.2091222	0.5902364	0.057	2.558

A recent study about the Canadian paper and pulp industry by Hailu and Veeman (2000) has estimated shadow prices for BOD and SS using an input distance function. The year-wise estimates of shadow prices obtained using aggregate time series data for the period 1959 to 1994 are reported. The average shadow prices for BOD and SS for the period 1990-94 are reported as 436 and 663 Canadian dollars per ton. An earlier study by Fare et al. (1993)[8] about the paper and pulp industry in the US has reported a very high shadow price of 1043.4 US dollars per ton of BOD at 1976 prices. This study has also reported very high shadow prices for air pollutants SPM and SO_x. They are respectively, 25,270.0 and 3,696.6 US dollars per ton at 1976 prices. Coggins and Swinton (1996) have estimated the shadow price of SO_2 emissions by coal-burning electric utilities in Wisconsin as 322.869 US dollars per ton at 1992 prices. Kumar (1999) has estimated the shadow price of SPM for thermal power generation in India using output distance function amounting to Rs. 326,180 per ton at 1993 prices.

5. Shadow Prices of Bad Outputs and the Design of Instruments

The shadow prices of BOD and COD which may be interpreted as the marginal costs of pollution abatement are found to be increasing with the degree of compliance of firms. Taking the index of non-compliance by the firms as the ratio of effluent concentrations of BOD, COD, and SS, it is found that the higher the index, the lower the shadow price. That means there is an increasing marginal cost of abatement. Considering the logarithm of shadow price as a dependent variable and the logarithm of effluent concentration and the waste water volume as independent variables, the estimates of the marginal cost of abatement of BOD, COD, and SS are given as follows:

$$\ln BODS = -3.914 - 0.004 \ln W - 0.013 \ln BODC, \quad R^2 = 0.0003$$
$$(-9.841) \quad (-0.131) \quad (0.041)$$

$$\ln CODS = 0.357 - 0.1999 \ln W - 0.096 \ln BODC. \quad R^2 = 0.138 \qquad (6)$$

[8] They have used data reported in Pitman, 1981 and 1983 for thirty paper and pulp mills operating in Wisconsin in 1976.

$$(0.857) \quad (-7.038) \qquad (-2.114)$$

$$\ln SSS = -2.438 - 0.094 \ln W - 0.012 \ln SSC, \quad R^2 = 0.030$$
$$(-5.987) \quad (-3.122) \qquad (-0.260)$$

Note: Figures in brackets are t values.

BODS: BOD shadow price

CODS: COD shadow price

SSS: SS shadow price

W: Waste water volume

In the case of COD there is a statistically significant negative relationship between the shadow price and the compliance index implying that the higher the degree of compliance the higher is the marginal cost. However, in the case of BOD, and SS, the relationship is negative but not statistically significant. Also, the estimates show that the shadow prices of undesirable outputs fall with the waste water volume in the case of BOD, COD, and SS. In other words, there is a falling marginal cost with respect to pollution load reductions or scale economies in the pollution abatement [9].

The above estimated marginal cost of abatement functions are useful in designing pollution taxes in India for controlling water pollution. The standards given for BOD, COD, and SS are respectively 35mg/l, 250mg/l, and 100mg/l. Following the taxes-standards approach (Buamol and Oates, 1988) if taxes are designed and levied such that the tax on each pollutant is equal to the marginal cost of abatement corresponding to the standard, the polluting firms will have incentives to comply with the standards. Using the estimates of marginal cost of abatement based on conventional cost functions, the earlier studies in India (Mehta et al.1995; Murty et al. 1999) have also dealt with the problem designing the pollution taxes using the taxes standards approach. The taxes on BOD, COD, and SS are respectively estimated as Rs. 20,157, Rs. 48,826, and Rs. 21,444 as given in Table 5.

Table 7: Estimates of Pollution Taxes per Ton of Pollution Load as per the Taxes Standards Approach (Rs. at 1996-97 prices)

BOD	COD	SS
20157	48826	21444

6. Monetary and Physical Accounts

[9] Mehta et al., 1995; Murty et al., 1999; Pandey, 1998; and Misra, 1999.

Physical accounts of influent and effluent loads, pollution reduction actually obtained, and pollution reductions required as per the standards for the Indian water pollution industry are reported in Table8. For estimating environmentally-corrected NNP, estimates of net additions to the stocks of pollutants in the environmental media are needed. The effluent loads of BOD, COD, and SS generated by the industry in a given year are additions to the stocks of these pollutants in the environmental media. Depending upon the natural assimilative capacity of the environmental media to absorb certain pollution loads without affecting itself, the industry makes additions to the stocks. If the stocks of pollutants in the environment have already reached the levels at which the natural assimilative capacity is zero, the effluent loads generated by the industry are simply additions to the stocks. Assuming that the standards for water pollution in India are fixed such that the pollution loads generated by the industry are equal to the natural assimilative capacity of water resources, there will be net additions to the stocks if firms do not meet the standards. For example, the effluent loads of BOD, COD, and SS for the Indian industry are respectively, Rs. 470,700.04, 2408,572.98, and 398,622.71 tons during the year 1997-98. The effluent loads as per the standards are respectively 95,878.58, 798,991.518, and 319,598.582 tons. The difference between the effluent load actually generated by the industry and the effluent load as per the standards could be taken as net addition to the stock of pollutants. In this case, for estimating environmentally corrected NNP after accounting for industrial pollution, only the value of this net addition to the stock of pollutant has to be deducted from the conventional NNP. The net additions to the stocks of BOD, COD, and SS in the environmental media due to industrial pollution in India during the year 1997-98 are estimated as 374,821.457, 1609,581.46, and 79,024.134 tons respectively as given in Table10.

Table 9 provides monetary accounts of industrial pollution in India. It provides estimates of monetary values of effluent loads, and load reduction required as per the standards. The monetary value of net additions to stocks of BOD, COD, and SS are estimated as Rs. 74,626.584 million for the year 1996-97, and Rs. 87,780.289 million for the year 1997-98 as reported in Table10. The estimates of net national product (NNP) for India for the year 1996-97, and 1997-98 at 1996-97 prices are given as Rs 10,939,610 million and Rs. 11,731,393. The environmentally corrected NNP for India, corrected for industrial pollution is estimated as Rs. 10,864,983.42 (Rs. 10,939,610 –74,626.584) million for the year 1996-97 and Rs. 11,643,613.3 (Rs. 11,731,393 – 87,780.289) million for the year 1997-98.

Table 8: Physical Accounts of Water Pollution Loads for Indian Industry

		Physical Accounts					
		BOD		COD		SS	
		1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
1.	Turnover	3,025,980.9	3,559,341.2	3,025,980.9	3,559,341.2	3,025,980.9	3,559,341.2
2.	Waste water volume	27,170,803,344	31,959,937,281	27,170,803,344	31,959,937,281	27,170,803,344	31,959,937,
3.	Influent Load	4,431,190.45	52,262,645.39	298,635,385.8	351,272,948.3	431,724,215.7	507,820,055
4.	Effluent Load	400,166.56	470,700.044	2,047,653.041	2,408,572.98	338,889.884	398,622.71
5.	Load reduced	44,031,023.88	51,791,945.34	296,587,732.7	348,864,375.4	431,385,325.8	507,421,432
6.	Load as per the standards	81,511.368	95,878.58	679,264.206	798,991.518	271,707.36	319,598.582
7.	Load reduction required as per standards	318,655.192	374,821.457	1,368,388.835	1,609,581.46	67,182.522	79,024.1345

Table 9: Monetary Accounts of Water Pollution Loads for Indian Industry (1996-97 prices)

Monetary Accounts							
		BOD		COD		SS	
		1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
1.	Turnover	3,025,980.9	3,559,341.2	3,025,980.9	3,559,341.2	3,025,980.9	3,559,341.2
2.	Waste water volume	27,170,803,344	31,959,937,281	27,170,803,344	31,959,937,281	27,170,803,344	31,959,937,281
3.	Effluent Load	5,318.25	6,255.651	103,657.3161	121,927.99	5,651.463	6,647.591
4.	Load reduction required as per standards	4,234.9594	4,981.4146	69,271.263	81,481.038	1,120.3626	1,317.838
5.	Load as per standards	1083.294	1274.236	34386.052	40446.948	4531.1006	5329.7538

Table 10: Physical and Monetary Accounts of Additions to Stock of Pollutants by Indian Industry

Physical Net Addition to the Stock of Pollutants			Monetary Value of Net Addition to Stock of Pollutants (Rs. millions)	
Pollutant	1996-97	1997-98	1996-97	1997-98
BOD	318,655.198	374,821.457	4,234.959	4,981.414
COD	1,368,388.83	1,609,581.46	69,271.263	81,481.037
SS	67,182.523	79,024.134	1,120.362	1,317.838
Total			74,626.584	87,780.289

7. Conclusion

Estimates of shadow prices of bad outputs or marginal costs of pollution abatement are made for the Indian industry. The primary data collected through two surveys of the firms during the period 1994-95 to 2000-01 for a large number of polluting firms in the Indian industry are used to estimate output distance functions. The surveys provide detailed data on water pollution while the data for air pollution is very limited due to a poor response from the surveyed firms about air pollution. Therefore, the estimates of shadow prices for three major water pollutants, BOD, COD, and SS that are made using the estimates of parameters of output distance function are reliable estimates. A large variation in the shadow prices of bad outputs across the observations is attributable to the variations in the degree of compliance across the firms.

It is shown that the estimates of shadow prices of bad outputs made in this paper could be used for designing pollutant-specific taxes to meet the prescribed standards, and the estimation of environmentally-corrected NNP, adjusted for industrial pollution. The estimated marginal cost of abatement functions for BOD, COD, and SS have displayed the property of raising marginal costs with respect to reductions in effluent concentrations. The estimated pollution taxes for making the firms comply with the national standards of 35mg/l for BOD, 250mg/l for COD, and 100mg/l for SS are Rs. 20,157, Rs. 48,826, and Rs. 21,444.

The estimates of physical and monetary accounts of industrial pollution in India given in this paper provide inputs for developing environmental and economic accounts using the United Nations methodology of integrated environmental and economic accounting. The monetary value of net additions to stocks of BOD, COD, and SS are estimated as Rs. 87,780.289 million for the year 1997-98. Given the estimate of net national product (NNP) for India for the year 1997-98 as Rs. 11,731,393 million at 1996-97 prices, the environmentally-corrected NNP for India, corrected for industrial pollution is estimated as Rs. 116,436,133 (11,731,393- 87,780.289) millions for the year 1997-98.

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