Estimation of Marginal Abatement Cost of Air Pollution in Durgapur City of West Bengal

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Abstract

Air pollution in industrial cities with emissions from firms is a growing problem in India. Durgapur, one of the growing industrial cities in eastern India, covering a host of industries, suffers from similar problems. The paper estimates the marginal abatement cost of air pollution of industries in Durgapur, West Bengal. We model the technology of a firm with output-distance function. Here the linear programming approach is adopted to estimate the shadow prices and distance values. Results reveal that there is a wide variation in shadow prices of Suspended Particulate Matter and distance values between firms under particular category of industries thus indicating the variability in the degree of compliance, use of resources and the vintages of capital. In this context the paper suggests policies for air quality management in urban industrial areas of West Bengal which will help to achieve sustainable industrial development.

Keywords: *Output Distance Function, Shadow Prices, Distance Values*

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Introduction

The study focuses on the estimation of marginal abatement cost of air pollution of industries in Durgapur, one of the growing industrial towns of eastern India and to suggest policies for air quality management in urban areas of West Bengal. The city has a host of industries which include thermal power, Iron and steel, Ferro alloys, Sponge iron, Cement, Industry chemicals, Boilers parts, Fertilizer, Cable manufacturing and Mining machinery. These industries fall under large scale, medium scale as well as small scale industries. Emissions from most of these industries (thermal power, iron and steel, sponge and ferro alloys) pose high health risks not only to the residents of the industrial city but also to other neighbouring towns and districts. There is now a great deal of legislation, regulation and intervention by the state for protecting the environment as a result of environmental consciousness of the civil society. An elaborate network of Central and State Pollution Control Boards is in place. The Central Pollution Control Board (CPCB) along with the State Pollution Control Board (SPCB) has laid down standards for the ambient air quality.

Discussion on emission control brings an important issue of sustainable industrial development. The firms have to spend some of its resources on emission control devices to reduce the pollution loads so as to meet the necessary air quality standards[1]. With resource constraints they 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 reduced output of the firm[2]. If all the firms in the industry meet the standards, the value of the reduced output of the firms is the cost of sustainable industrial development. Now reduced output means revenue foregone. So from this analysis we see that there must be an efficient path which the firms should follow that will help them to maximize their outputs and revenue[3] and also maintain the minimal emission as prescribed by the statutory boards. The firms will themselves choose the way to meet the standards prescribed by the regulatory boards. The present paper addresses the following question focusing on Durgapur, West Bengal. Is the existing environmental regulation leading to efficient use of pollution control technologies of industries?

The rest of the paper is organized as follows: Section 1 reviews briefly the literature. Section 2 presents the model. Section 3 reports the data collection and its processing. Model estimation and analysis of results are elaborated in section 4. Section 5 concludes the paper with policy implications.

1. Literature

Literatures on the estimation of the pollution abatement costs are growing but the studies in India are not large. There are a number of empirical studies beginning with the early eighties that examine the impact of environmental regulations on the economic performance of firms. The United Nations Manual (1993 a, b) of Integrated Environmental and Economic Accounting provides descriptions of maintenance cost or cost of sustainable use of environmental resources. Fare et al. (1993) have used output distance function approach to derive shadow prices for pollutants for USA. They showed how to adjust efficiency measures in the presence of undesirable outputs and also how to estimate output distance functions as frontiers in order to generate shadow prices of the undesirable outputs that are required to make both types of adjustment. Similarly Coggins & Swinton (1996)

estimate the shadow price of SO_2 abatement for Wisconsin coal burning utility plants, USA by using an output distance function approach. ÿþRecently FäRE (2003) estimates the pollution abatement costs associated with environmental regulations for 1994 and 1995 incurred by electric power plants of US. The estimates of pollution abatement costs generated by the joint production model are then compared with survey estimates of pollution abatement costs incurred by power plants.

Some attempts have been made to measure the effect of pollution regulations on total factor productivity growth. Recently stochastic translog output distance functions were estimated by using panel data from dairy farms over the period 1991- 94 for three European regions (Northern Germany, the Netherlands and Poland) separately and for all regions together by Brümmer, Glauben and Thijssen (1999) for the manufacturing industries of USA by looking at the following components: technical change, change in technical efficiency, scale component, and violations of the profit maximizing assumption for inputs and outputs. The directional distance function is used by Domazlicky and Weber (2004) to measure the lost chemical manufacturing output and the overproduction of toxic chemical releases for the US chemical industry. Total factor productivity growth is decomposed into a product of efficiency change and technical change. Accounting for toxic chemical releases, productivity grows at an annual rate of between 2.4% and 6.9%. They found no evidence that environmental protection measures reduce productivity growth.

Another directional output distance function has been attempted by Marklund (2004) to compute and evaluate producers' marginal abatement costs (MACs) of Swedish pulp industry. These costs are obtained by calculating shadow prices of bad outputs from the production technology, which is represented by the estimated directional output distance function. Here the regulatory authority has granted each producing plant a maximally allowed emission level. The main focus is on whether the calculated MACs reveal that differences between counties for, e.g., economical characteristics, were influential when the authority, during 1983-1990, restricted 12 geographically scattered pulp plants regarding emissions. The result indicates that the MACs vary between many of the plants and that county differences were taken into account when imposing environmental restrictions on the plants. Similarly FäRE (2003) derives the relationship between environmental production functions and environmental directional distance functions. These two approaches make different assumptions when modeling the joint production of good and bad outputs. The environmental production function credits a producer solely for expanding good output production, while the directional environmental distance function credits a producer for simultaneously increasing production of the good output and reducing production of bad outputs. Estimates of technical efficiency and pollution abatement costs are calculated using data from coal-fired power plants. These results provide the empirical basis for comparing the environmental production function to the environmental directional distance function.

Distance functions have also the advantage that they can be used for decomposing the TFP growth into technical change, measuring the outward shift of the production function, and efficiency changes, measuring the relative change of position of a country with respect to the global production function. By applying a distance function approach to global data, including traditional output, labour and capital inputs and unwanted output, carbon dioxide (CO2) and sulphur dioxide (SO2), Lindmark and Vikstrom(2003) investigated the patterns of TFP convergence in a setting where welfare losses from environmental

degradation is included. The overall purpose is to test the hypotheses that can be deducted from New Growth Theory namely that high-income countries should experience higher TFP growth than poorer and that technological change is more important than efficiency gains for high-income countries and vice versa for low-income countries. On a more explorative level they investigate whether these relationships are true and how much overall productivity is affected when 'bads' are introduced to the output bundle. The investigation is based on 59 countries. Results revealed that the differences in total productivity without bad outputs are more in line with what should be expected from traditional neo-classical growth theory than with the expectations from the endogeneous growth theory. The absence of a distinct correlation between income level and TFP growth rate suggests that technology can be seen as an exogenous factor, even if there are large differences between specific countries. The endogeneous growth theory indicates that leader countries continue to have an advantage in TFP growth. The absence of such a trend lends limited support to the endogeneous view on productivity differences.

Recently DEA application is also growing in this output distance function literature. Kuosmanen and Kortelainen (2004) present basic principles of DEA and evaluate its application possibilities for a range of environmental valuation problems. More specifically, how DEA has to be adjusted to the context of environmental performance, eco-efficiency and Cost-Benefit analysis (CBA). By modifying the traditional DEA framework to the specific features and purposes of environmental application they show that the valuation principles to which DEA is based on can offer useful insights and complement the conventional toolbox of environmental economists in valuation of the environmental services in general.

The literature on output distance function in Indian context is not large. Murty & Kumar (2002) have used the methodology of output distance function for estimating the cost of water pollution abatement measure of the Indian industry. This paper attempts the valuation and accounting of industrial water pollution in India for the year 1995 and 2000. 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. Similar study by Murty, Kumar and Paul (2001) for India has shown with the help of output and input distance functions the effect of environmental regulation on the productive efficiency of firms. Again another study by Murty and Kumar (2001) suggests the effect of environmental regulation relating to water pollution by the Indian industry on the productive efficiency of firms. The main empirical result is that the technical efficiency of firms increases with the intensity of environmental regulation and the water conservation efforts there by supporting the Porter hypothesis.

Rao (2001) has carried out the input-distance function for paper industry in India. Coelli & Singh (2003) measured the technical and allocative efficiency with application to Indian dairy processing plants.

Output distance function studies on air pollution are rare in the literature especially in India. 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. Shanmugam & Kulshreshtha (2002) employ the stochastic frontier production function methodology to measure the technical efficiency of Indian thermal power plants, using latest available panel data. Efficiency varies widely across

firms and regions and is time-variant. Mean technical efficiency increased from 79 per cent in 1994-95 to 85 per cent in 1996-97, which indicates that there is scope for raising power production, without employing additional resources. The findings can aid policy-makers and international agencies in adopting appropriate strategies to improve power generation in India. Kumar & Gupta (2003) measure resource use efficiency of electricity generating plants in the United States under the SO_2 trading regime.

Output distance function study is not limited to air and water pollution. A separate kind of study has been estimated using the production data from 50 organisations by Misra and Kant (2001) on stochastic output distance function characterizing the production structure of JFM organizations, in the Gujarat state of India. The distance function includes economic, biological and social outputs, and conventional – land, labour, and capital – as well as non-conventional – homogeneity of village community, dependence of village community on forest, presence of village leadership, and other factors. A two-stage procedure, combining the deterministic linear programming with a stochastic econometric model, is employed to estimate the output distance function. The results are used to calculate the efficiency and relative shadow prices of social and biological outputs of different village-level JFM organizations.

As already mentioned the studies in India are more sectors specific. The current paper concentrates on Durgapur, one of the biggest industrial belts in eastern India with a simultaneous existence of a number of industries. The output distance function will be used to estimate the abatement cost of air pollution of industries in Durgapur.

2. Model Formulation

We model the technology of a firm with output-distance function. The distance function can provide useful tool for assessing environmental policy. Methodology will prove useful in other industries facing new or newly stringent environmental restrictions. Another advantage of this approach lies in its modest data requirements. It relies only on readily available observed output and input data.

Many industries generate multiple outputs. The output distance function in the theory of production helps to characterize the technology of a firm producing a vector of output jointly and to define their shadow prices and opportunity cost. In case of a firm generating air pollution the output distance function can be used to represent the firm technology as a joint production of good and bad outputs, the bad output being the pollution. With the assumption of weak disposability of outputs, the shadow prices of pollutants can be defined in terms of positive output or revenue foregone. The distance functions are more general representation of production technology in comparison to conventional cost, production, or profit functions and can successfully tackle the problem of multiple outputs (references.

The shadow prices of the undesirable outputs calculated here reflect the opportunity cost to individual firms of the restrictions they face on disposability of these undesirable outputs. These shadow prices will reflect the impact of regulations faced by the firms, and they can be used to assess the cost effectiveness.

We will now explain the methods of estimating abatement cost of air pollution for industry and power plant sectors, which are the important contributors to SPM[4], SO_2 and NOx emissions in Durgapur, West Bengal.

Output Distance Function Approach

The production function actually means the maximum output that can be produced from an exogenously given input vector while the cost function derives the minimum cost to produce the exogenously given output. The output distance function generalizes these notions to a multi output case.

Suppose a firm employs input vector $x \in \Re^N_+$ to produce output vector $u \in \Re^M_+$. Let L(x) be the feasible output set for the given input vector x and I (u) is the input requirement set for a given output vector u. Now the technology set is defined as

$$P = \{(u, x) \in \Re_+^{M+N}\ u \in L(x),\ x \in I(u)\} \quad (1)$$

The output distance function is defined as

$$D_f(u, x) = \min \{\mu > 0 : (u/\mu) \in L(x)\} \forall\ x \in \Re^N_+ \quad (2)$$

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

If u = 0 is on the boundary of L(x), then D(x, u) =1. If $u \in$ int L(x) then D(x, u) < 1. It must also be true that D(x, u) $\geq$ 0.

The distance function D (x, u) is continuous, increasing and convex in u for each x, homogeneous of degree 1 in outputs, and quasi-concave and decreasing in x.

The following are the properties of the output distance function

a. $D_f(0,u) = +\infty$ for $u \geq 0$
b. $D_f(x,0) = 0$ for all x in $\Re^N$ that is inaction is possible

c. x ‘ ≥ x implies that $D_f(x', u) \le D_f(x, u)$ which means more input the less efficient will be the production.

d. $D_f(x, \lambda u) = \lambda\, D_f(x, u)$ for $\lambda>0$ which means positive linear homogeneity.

e. $D_f(x, u)$ is convex in u.

When the firm produces both good and bad outputs[5] then the question of disposability will arises. The strong and weak disposability implies:

If $(u1, u2) \in L(x)$ and $0 \le u1^* \le u1$, $0 \le u2^* \le u2 \Rightarrow (u1^*, u2^*) \in L(x)$

The above condition defines that we can reduce some outputs given the other outputs or without reducing them.

If $u \in L(x)$ and $0 \le \mu \le 1 \Rightarrow \mu u \in L(x)$ it simply reveals the weak disposability i.e. a firm can reduce the bad output only by decreasing simultaneously the output of desirable produce.

The shadow prices of bad outputs using output distance function is originally from Shephard (1970). Suppose the observed price of the mth good output r_m^o equals its absolute shadow price r_m'. We shall use the observed price of a desirable output as our normalizing price, since desirable outputs are observable, market determined prices (which the undesirable outputs do not). For all $m' \neq m^o$, **absolute shadow prices** r_m' are given by

$$r_{m'} = r_m^o \cdot \frac{\delta D_f(x, u) / \delta u_{m'}}{\delta D_f(x, u) / \delta u_m^o} \qquad (3)$$

The approach employed here does not require the information on regulatory constraints; shadow prices reflect the trade off between desirable and undesirable output at the actual mix of outputs which may or may not be consistent with the maximum allowable under regulation.

In order to implement our shadow price expression of pollutants (bad outputs), for the air polluting industries using the above equation we need to parameterize and calculate the parameters of an output distance function. Here we will choose to parameterize $D_f(x, u)$ as a translog function, which is the functional form employed to model technology by Pittman (1983). This functional form has the advantage of flexibility. It does not impose strong disposability of outputs.

$$\ln D_f(x, u) = \alpha_o + \sum_{n=1}^{N} \beta_n \ln x_n + \sum_{m=1}^{M} \alpha_m \ln u_m + 1/2 \sum_{n=1}^{N}\sum_{n'=1}^{N} \beta_{nn'} (\ln x_n)(\ln x_{n'}) + 1/2 \sum_{m=1}^{M}\sum_{m'=1}^{M} \alpha_{mm'} (\ln u_m)(\ln u_{m'}) + \sum_{n=1}^{N}\sum_{m=1}^{M} \gamma_{nm} (\ln x_n)(\ln u_m) \qquad (4)$$

Where x and u are Nx1 and Mx1 vectors of inputs and outputs respectively. For estimating the output distance function, the technology of each plant is described by joint outputs (both good and bad) and inputs.

To estimate the parameters of the output distance function we will use programming model.

Estimation Of Output Distance Function: Programming Model

A linear programming technique is used to estimate the parameters of the deterministic translog output distance function (Aigner and Chu 1968). Let k=1, 2...K, index the observations in the data set. Let m = 1...M denote the total number of outputs produced by a firm. We assume that the first output is good output and the rest i.e. m= 2...M denote the bad outputs.

This is accomplished by solving the problem,

$$\text{Max} \sum_{k=1}^{K} [\ln D_f(x^k, u^k) - \ln 1], \qquad (5)$$

Subject to

(i) $\ln D_f(x^k, u^k) \le 0$ where k=1 ………..K

(ii) $(\delta \ln D_f(x^k, u^k)) / (\delta \ln u_1^k) \ge 0$ where k=1 ………..K

(iii) $(\delta \ln D_f(x^k, u^k)) / (\delta \ln u_m^k) \le 0$ where k=1 ………..K , m = 2………..M

(iv) $\Sigma\alpha_m = 1$ where m = 1, 2..…..M

(v) $\Sigma\alpha_{mm'} = \Sigma\gamma_{nm} = 0$

$\alpha_{mm'} = \alpha_{m'm} = 0$ m = 1, 2, …, M m' = 1, 2, …, M

$\beta_{nn'} = \beta_{n'n}$ n = 1, 2, …., N n' = 1, 2, …., N

Here, first is the desirable and the rest of (M-1) outputs are undesirable and ln D_f (*x*, *u*) has an explicit translog functional form. 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 D_f (x^k, u^k) is less than or equal to zero and the deviation for the frontier for observation k, 1n D_f (x^k, u^k) -1n1, is less than or equal to zero; hence the max. The first set of constraints, i.e. (i) restrict the individual observations to be on or 'below' the frontier of the technology, this is a frontier approach. The constraints in (ii) ensure that the desirable outputs have non-negative shadow prices and those in (iii) ensure that the undesirable outputs have non positive shadow prices. The constraints in (iv) impose homogeneity of degree +1 in inputs (which also ensures that technology satisfies weak disposability of outputs). The final set of constraints in (v) imposes symmetry.

From this we shall estimate the **parameters** of output distance function for different industries and power plants in Durgapur. Estimates of industry specific **shadow prices** for bad outputs based on the parameters of the translog output distance function will be made. These shadow prices can be interpreted as marginal cost of air pollution abatement. Methodology will prove useful in other industries facing new or newly stringent environmental restrictions. Another advantage of this approach lies in its modest data requirements. It relies only on readily available observed output and input data.

3. Data

The empirical work is carried out by data collected from direct field survey in Durgapur, an industrial town located in West Bengal, India. The data are collected from various category of industries situated in the surveyed area. Our survey has incorporated the two integrated steel plants (DSP & ASP), three thermal power plants (DPL, DTPS & NSPCL), six ferro alloy plants (Shyam, Sova, Monate, Bhaskar Shrachi, Srinivas & Haldia Steel), and three sponge iron plants (Adhunik, SPS & Ritesh). The other category considers two units namely ABL and PCBL. PCBL is mostly a producer of carbon black used as industrial electrodes and ABL is a producer of boiler parts used in thermal power plants. The data collected from all these units are on the different variables. As far the inputs are concerned data are collected on the annual consumption of raw materials, fuel, capital investment and also labour. The data for all the units are collected for four consecutive years viz: 2000-01, 2001-02, 2002-03 and 2003-4. As regards output data both the desirable outputs and undesirable outputs are taken. The desirable output is the finished product which varies industry wise and the undesirable outputs incorporate the emissions like SPM, PM, SO_2, NOx and CO. Here we have considered only SPM due to the paucity of data. The undesirable output (SPM) is expressed in mg/nm3 (milligram per normal meter cube). This unit is converted into tons per year on the basis of the formula given in the notes[6].

Inputs data and output are obtained from the industries in quantity terms. Using the relevant price information of various inputs and outputs we have calculates the values for the same at constant 2000 prices. However, the relevant data are not available for all the years for all the firms. The information collected constitutes unbalanced panel data with 48 observations on all the relevant variables.

The information on pollution control devices are collected from the individual industries on different areas like installation cost, running cost of those devices and the type of devices. The installation cost is collected to reflect the addition to the capital cost. As far the running cost is concerned it has been incorporated in the input cost. Table A1, in Appendix A, represents the description of the pollution control devices used in the different firms in Durgapur.

It is important in this regard to mention that apart from the data collection from the individual plants a good number of valuable information is also collected from the office of West Bengal Pollution Control Board in Durgapur and Calcutta. Particularly some technical specifications, conversions, the stack emission and the ambient air quality standards are collected from those offices.

4. Model Estimation And Analysis Of Results

4.1 Linear Programming Estimate

The output distance function is solved as a linear programming problem using the 48 observations. The estimates are calculated using the GAMS software. The resulting parameter estimates appear in Table 4.1.

These estimates (table 4.1) are used to compute the values of the shadow prices for industries and also for each firm. These values are averaged across the years. The estimates of industry-specific shadow prices for bad output viz. SPM based on the parameters of the translog output distance function are given in table 4.2.

Table 4.1: Parameter Values

Variables	Parameter	Value	Variables	Parameter	Value	Variables	Parameter	Value
	α_0	6.446	X2*X2	β_{22}	-0.002	Y1*Y2	α_{12}	0.042
Y1	α_1	1.059	X2*X3	β_{23}	-0.012	Y2*Y1	α_{21}	0.042
Y2	α_2	-0.059	X2*X4	β_{24}	-0.030	Y2*Y2	α_{22}	0.023
X1	β_1	-1.048	X3*X1	β_{31}	0.026	X1*Y1	γ_{11}	-0.027
X2	β_2	0.130	X3*X2	β_{32}	-0.012	X1*Y2	γ_{12}	-0.023
X3	β_3	0.074	X3*X3	β_{33}	0.011	X2*Y1	γ_{21}	0.048
X3	β_4	-0.970	X3*X4	β_{34}	-0.026	X2*Y2	γ_{22}	-0.016
X1*X1	β_{11}	0.064	X4*X1	β_{41}	0.010	X3*Y1	γ_{31}	-0.002
X1*X2	β_{12}	-0.010	X4*X2	β_{42}	-0.30	X3*Y2	γ_{32}	-0.005
X1*X3	β_{13}	0.026	X4*X3	β_{43}	0.026	X4*Y1	γ_{41}	0.035
X1*X4	β_{14}	0.010	X4*X4	β_{44}	0.060	X4*Y2	γ_{42}	-0.010
X2*X1	β_{21}	-0.010	Y1*Y1	α_{11}	-0.108			

Y1- Sales (Rs in millions/yr) X1 - Raw Material (Rs in millions/yr) X3 – Capital (Rs in millions/yr)

Y2 - SPM (Tons /yr) X2 – Labour (Rs in millions/yr) X4 – Fuel (Rupees in millions/yr)

The shadow prices of SPM may be interpreted as the marginal costs of pollution abatement. These shadow prices are negative, reflecting desirable output and revenue foregone as a result of reducing the emission by one unit (ton) per year.

We can see from the table that the average shadow price for the air polluting industries in Durgapur is Rs 0.7165 million. This means that in order to reduce one ton of SPM the industry has to forego nearly Rs 0.7165 million worth of good output. The range of the shadow prices for SPM is Rs 0.034 million for sponge iron to Rs 2.7693 million for the integrated iron and steel plants. The study consists of different types of industries ranging from power plants to integrated steel plants which are not homogeneous and rather dissimilar entities. So it is more justifiable to highlight and explain the intra industry variations rather than the inter industry variations because of the wide spectrum of industries considered in our study. This wide variation can be explained by the variation in the degree of compliance as measured by the ratio of pollutant loads and the sales value and the vintages of capital used by the firms for the production of desirable output and pollution abatement. The shadow prices of SPM, which may be interpreted as the marginal costs of pollution abatement, are found to be increasing with the degree of compliance of the firms. We also use the parameter estimates (table 4.1) to calculate the four year industry average output distance value. This is appearing in column 2 of table 4.2.

The average distance value for the industries in Durgapur is 0.949. This indicates that productive efficiency in this industry can be increased approximately by 5% given the technology currently in use. For the ferro steel plant , thermal power plants and the industries falling under 'others' category, the distance values are 0.960, 0.956 and 0.950 respectively. As far as the sponge plants are concerned, distance values suggest that they are operating approximately 9% below the frontier. Now interestingly, like the shadow prices, variations in distance values are also not only observed within the industries but also across firms within a particular category of industry. This is evident from table 4.3.

Table 4.2: Industry specific shadow prices and distance values

Industry	Shadow prices (million rupees/ton)	Distance Values
Ferro Alloys	-0.1987	0.960
Sponge Iron	-0.0341	0.911
Iron and Steel	-2.769	0.968
Thermal Power	-0.2245	0.956
Others	-0.3560	0.950
Average	**-0.7165**	**0.949**

The range of the shadow prices for Ferro and sponge lies between 0.01million Rs/ton to 0.68 million Rs/ton and 0.004 million Rs/ton to 0.05 million Rs/ton respectively. On the other hand the thermal plants have almost same shadow prices (0.20 million Rs/ton to 0.24 million Rs/ton). The most striking differences in shadow prices has been observed in case of Iron and steel industry (0.57 million Rs/ton to 4.96 million Rs/ton). The variations can be attributed mostly to levels of capacity utilization, the quality of raw materials, the vintages of capital and the pollution control devices.

Let us consider the case for between two ferro alloys unit. Bhaskar Shrachi Alloys Ltd and Shyam Ferro alloys limited both have two electric arc furnaces (3.5 and & 7.5 MVA) with same capacity but the utilization of the furnaces are largely different. We see that the shadow price and distance value for Bhaskar is greater than Shyam (table 4.3). Again Sova and Haldia individually have three furnaces with same installed capacity (two numbers of 3.5 MVA and one 7.5 MVA) but utilized differently. Haldia have much higher shadow prices compared to Sova. The shadow price of Haldia is estimated to be Rs 0.123 million and for Sova to be Rs 0.010 million and this indicates the large differences in the shadow prices. The distance values for the same are 0.976 and 0.964 respectively. As far the quality of the raw materials is concerned, some of the plants are found to use relatively low grade coal quality, having high ash content. Information suggests that Srinivas uses the poorest quality of coal while that of Bhaskar and Monate uses much superior quality of coal. Accordingly Monate and Bhaskar have higher distance values and shadow prices. The shadow prices for Bhaskar and Monate are Rs 0.688 million and Rs 0.246 million and the shadow price for Srinivas is Rs 0.89 million. In this regard it is mentionable that the vintages do not come into play as these ferro plants mostly came up in the year 1999. Similar story goes for the sponge iron plants. As far the sponge iron plants are concerned, the large differences in the shadow prices can also be attributed to the difference in the level of capacity utilization of the plants, and the differences in the usage of the quality of raw materials. Among the integrated steel plants the operational efficiency of DSP is relatively higher than ASP. Among the various factors that influence the efficiencies, the vintages of capital do really play an important role. The DSP, for modernization, made a huge investment of rupees five thousand crores between the periods 1992 to 1995. This included the complete closure of the old polluting steel melting shop and the incorporation of the advanced Basic Oxygen Furnace (BOF) for steel production. Accordingly the fuel cost has reduced drastically as the high calorific value gas generated in the Blast furnace is reutilized as a fuel in BOF for the conversion of iron to steel. Modernisations have been made in some of the existing polluting units like the Raw Materials Handling Plant (RMHP), Sinter Plant and the Coke Oven, to name a few. There was an additional investment of nearly Rs 250 crores for the pollution control devices. Field information suggests that there has not been much investment for the inclusion of newly sophisticated capital in ASP and they are still operating with the old capital from a nominal investment on pollution control devices (appendix).

Table 4.3: Firm Specific shadow price and distance values

	Firms	**Shadow Price in Million Rs/ton**	**Value of distance**
	Ferro		
1	Shyam	-0.03641	0.943
2	Sova	-0.01005	0.964
3	Monate	-0.24566	0.968
4	Bhaskar	-0.68847	0.988
5	Haldia	-0.12293	0.976
6	Srinivasan	-0.08877	0.924
	Sponge		
7	Adhunik	-0.0570	0.844
8	SPS	-0.0403	0.964
9	Ritesh	-0.0049	0.925
	Thermal		
10	NSPCL	-0.2404	0.939
11	DPL	-0.2088	0.991
12	DTPS	-0.2243	0.938
	Iron and Steel		
13	DSP	-4.9606	0.981
14	ASP	-0.5779	0.956
	Others		
15	Alstom	-0.02131	0.914
16	PCBL	-0.6908	0.987

As far the thermal power plants are concerned, information reveals that DTPS and NSPCL uses poor grade coal, having higher ash content compared to the coal used by DPL. Since coal is the major raw material used in the thermal power plants, differences in the quality of the coal play a big role in the operational efficiency as well as the undesirable emissions.

5. Conclusion And Policy Implication

The paper estimates the marginal abatement cost of air pollution of different industries in Durgapur city, West Bengal.

The output distance functions are used as analytical tools. The linear programming approach has been applied to reach the desired objective. From the parameter estimates of the translog output distance functions the firm specific shadow prices, distance values are obtained. Results reveal that the shadow prices of SPM vary widely across firms within a specific category of industry. Further, the integrated steel plants have the highest shadow prices and are also operating close to the optimal frontier. The two integrated steel plants are operating 3% below the optimal production frontier. The thermal power plants, the ferro alloys and the firms belonging to 'others' category, have fair distance values and a high shadow prices. But Sponge units are not good performers. The difference in firm specific and industry specific shadow prices of air pollution abatement cost reflects the difference in the levels of capacity utilization, the quality of raw materials, vintages of capital and the pollution control devices. The CPCB, WBPCB have an important role to play in making the plants use an optimal mix of the above mentioned plant operation. One of the traditional ways of forcing the plant to use the best mix is the Command and Control policies. This is what the boards have been following and are carrying on with the process. However, the present structure of the command and control steps of WBPCB are not transparent and in most cases taken in a holistic manner rather than sector specific. If the industries are found that the emissions have gone above the specified limit then a notification is provided which asks for the reason behind the increased level of emission. A check by the pollution control board (WBPCB) is again carried after some period. If the test results show that the industries

are still not meeting the standards then a hearing date is fixed by the West Bengal pollution control board regarding the future operations of the plant. In most cases the industries are asked to deposit a bank guarantee of some amount (fixed by the legal and technical expert). The question arises regarding the principle of fixation. There is no economic rationale behind the fixation of the amount rather it is fixed arbitrarily. A time of generally one year is given for the firms to install the necessary pollution control devices. If they achieve to do so then the bank guarantee is paid back (not the entire amount and depends on various cases) otherwise the entire amount is forfeited. This forfeited amount is used by the WBPCB for the improvement of the environmental quality in the industrial area as well as the nearby residential area. In this regard our findings suggest that instead of fixing the bank deposit arbitrarily the board can use the values of the shadow prices for fixing the amount. Further, to strengthen the Command and Control policies the current study suggests the board to identify standards for capacity utilization, quality of the raw materials, vintages of capital and control devices which will bring firms closer to the production frontier.

Moreover, there are a number of policy options available to the PCBs to make the firms comply with the standards. One of the good alternatives that can be applied is the tradable permit i.e. the idea of creating a market for pollution rights. The advantages of the tradeable permit system are the following: (a) the polluters can use their private information about technology, costs, etc., to achieve profit maximising levels of abatement. (b) The government's responsibility is limited only to setting ambient standards and monitoring the behaviour of the third party derives monopoly power once they get the contract. Based on the experiences gained in the operation of the secondary market, the government may design and implement better auction schemes.

Notes:

1) Standards are pollution specific not firm or industry.

2) This implies an assumption of a perfectly competitive market where firms cannot demand a higher price for their product.

3) Here revenue is not treated as profit.

4) SPM (Suspended Particulate Matter) is defined as a particle floating in the air with a diameter is below 10 µ m. The term suspended particulate matter covers a wide range of finely divided solids or liquids that may be dispersed into the air from combustion processes, industrial activities including power plants, mobile sources including diesel and gasoline-powered vehicles or natural sources. Studies have shown that high SPM concentrations in the air can have a detrimental impact on respiratory organs. The suspended particulates are important in relation to health not only because they persist in the atmosphere longer than larger particles, but also because they are small enough to be inhaled and to penetrate deeply into the respiratory tract.

5) The good output is the desirable output that firm produces and finally sales in the market whereas bad output is undesirable output as waste and pollutants produce during the production process.

6) Emissions (tons/year) = {E*24*D*V}
{1000000000}

Where E = Emissions in (mg/nm3)

V = Velocity of Gas flow (nm3/hr)

D = Plant Specific days of operations in a year

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Appendix A

Table A1: Pollution Control Devices and Years of introduction

Firms	Pollution Control Devices	Year of introduction
1. Ferro Alloy Plants		
a) Shyam Ferro Alloys Ltd	Wet Scrubber	2001
b) Sova Alloys Ispat Ltd	Bag Filter	2001
c) Monate Ferro Alloys Ltd	Bag Filter	1997
d) Bhaskar Shrachi Alloys Ltd	Bag Filter	2000
e) Srinivas Ferro Alloys Ltd	Bag Filter, Wet Scrubber	-
f) Haldia Steels Ltd	Bag Filter	-
2. Sponge Iron Plants		
a) Ritesh Trade fin Ltd	Multi Ventury Scrubber	2003
b) SPS Sponge Iron Ltd	Bag Filter, Electro Static Precipitator, Heat Exchanger	2002
c) Adhunik Ispat Limited	Electro Static Precipitator	2003
3. Integrated Steel Plants		
a) Durgapur Steel Plant (DSP)	Electro Static Precipitator, Multicellular Cyclone, Bag Filter, Multi Ventury Scrubber	1992(NI),1994(NI), 1996(NI), 2000(NI), 2002(NI)
b) Alloy Steel Plant (ASP)	Fume Extraction System, Dedusting System, Electro Static Precipitator, Bag Filter	1994(NI), 1997(NI),
4. Thermal Power Plants		
a) NTPC SAIL Power Corporation Ltd (NSPCL)		-
b) Durgapur Projects Ltd (DPL)	Electro Static Precipitator	1997(NI), 1998(NI), 1999(NI)
c) Durgapur Thermal Power Station (DTPS)	Electro Static Precipitator	1998(NI)
5. Others		
a) Phillips Carbon Black Limited (PCBL)	Bag Filter, Electro Static Precipitator	1999(NI)
b) Alstom Boilers Limited (ABL)	Electro Static Precipitator	2004(NI)

*NI- New Installation