Accounting for Cost of Environmentally Sustainable Industrial Development in Measuring Green GDP: A Case Study of Thermal Power Generation State of Andhra Pradesh in India*

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Abstarct

This paper provides alternative models for describing the production structures of polluting firms. One model considers pollution as an input in the production while another model regards pollution as a bad output jointly produced with good output. Both the models are estimated using the data about thermal power generation in the Indian state of Andhra Pradesh (AP). Estimates of shadow prices of pollutants and the maintenance cost or cost of environmentally sustainable generation of power are obtained. This estimated cost that has to be accounted in the estimation of Green GDP constitutes 2.8 percent of Sate Gross Domestic Product of AP.

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I. Introduction

The environment provides waste disposal services as productive inputs to industry. Given the environmental regulation producers place a value on these inputs similar to the way they value other conventional inputs such as labour, man made capital and materials. Environmental regulation meant for ensuring an environmentally sustainable industrial development imposes a cost on the industry. The UN methodology for an integrated environmental and economic accounting calls this cost as maintenance cost or the cost to the industry for maintaining the quality of environment at its natural regenerative level. Two alternative models in the theory of production are considered in this paper for estimating the maintenance cost. The first model considers the pollution load as one of the inputs and the production function and material balance condition in power generation as simultaneous equations. The second model describes the technology of power generation as one of producing jointly good output, power and bad output, pollution load, using the output distance function. In both the models, the processes of waste generation or material balance conditions are considered. In the first model, the material balance condition is explicitly incorporated while in the second model it is implicit in the production relation expressed in a reduced form as output distance function[1].

The producer demand price for waste disposal services from the environment could be defined as the value of marginal product in the case of the first model. Alternatively, it could be defined as the opportunity cost in terms of good output foregone to reduce bad output in the case of the second model. In any attempt to measure Green GDP, estimates of these shadow prices are needed to value changes in environmental quality brought out by the developmental activities.

The remaining paper is organized as follows: Section II describes the first model and its estimation using data for the thermal power generation in Andhra Pradesh (AP) state. Section III discusses the second model and its estimation using the same data set. Section IV presents the physical and monetary accounts of air pollution in the thermal power

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[1] Murty and Russell (2002) have shown that there could be problems in defining the shadow prices of pollution and finding the trade off between pollution and output along the production frontier in both these models. However, they have shown that modelling abatement as an intermediary input does yield the positive trade off and facilitates the definition of shadow prices of pollution.

sector in AP and a method of accounting for it in the estimation of Green GDP. Section V provides the conclusion.

II. A Model Describing Production and Pollution Generating Processes Considering Pollution as a Productive Input

The technology of a polluting firm could be described as containing two parts: T_1 a standard technology set, showing the way in which inputs get transformed into outputs and T_2 showing nature's residual generating mechanism[2]. Suppose that a firm employs a vector of inputs $x \in \Re^N_+$ to produce a vector of outputs $y \in \Re^M_+$., then $\Re^N_+$, $\Re^M_+$, 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*), the input requirement set for a given output vector *y*. Suppose the firm generates pollution z because it uses a certain input x_s (say SPM is generated because it uses coal). Now the technology sets are defined as,

$$T_1 = \{(y,x) \in \Re^{M+N} / y \in P(x)\}.$$

$$T_2 = \{(y,z,x) \in \Re^{M+N+1} / z = g(x_s)\}. \qquad (2.1)$$

$$T = T_1 \cap T_2.$$

Suppose now the firm involves itself in pollution abatement and produces abatement output y_a, in addition to conventional output represented by the output vector y and uses this abatement output to reduce pollution z. The technology sets in this case are defined as,

$$T_1 = \{(y,y_a,x) \in \Re^{M+N+1} / y \in P(x)\}.$$

$$T_2 = \{(y,y_a,z,x) \in \Re^{M+N+2} / z = g(y_a,x_s)\}. \qquad (2.2)$$

$$T = T_1 \cap T_2.$$

The model with abatement output and material balance condition as described in (2.2) above is estimated using data for thermal power generation in Andhra Pradesh state in India. The model for estimation is given as follows:

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[2] See Murty and Russell (2002) for a lucid description of technologies of a polluting firm with material balance condition and pollution abatement.

$$\ln y_i = a_1 + a_2 \ln x_{1i} + a_3 \ln x_{2i} + a_4 \ln x_{3i} + a_5 \ln x_{4i} + a_6 d_{1i} + a_7 d_{2i} + a_8 d_{3i} + a_9 d_{4i} + u_i \quad (2.3)$$

$$\ln z_i = b_1 + b_2 \ln x_{4i} + b_3 \ln y_i + v_i \, , \quad (2.4)$$

where x_1, x_2, x_3, and x_4 are respectively capital, labour, energy, and reduction in pollution load (abatement effort), and d_1 , d_2 , d_3 , and d_4 are dummy variables representing power plants, y and z are output (electricity generated), and actual pollution load, and u and v are disturbance terms. The inputs capital, labour, and energy are respectively measured as the value of capital services, wage bill, and expenditures on energy inputs. The values of all these variables are expressed at constant prices. The abatement effort (x_4) of the plant is measured as the pollution reduction obtained (difference between influent and effluent flows). Influent flows of each plant are estimated using engineering norms (x_7) or emission coefficients while the effluent flows (z) are the actual emissions by the plants after their abatement efforts. The analysis is done considering emissions of Suspended Particulate Matter (SPM) as pollution loads. Equation (2.3) is a simple Cobb-Douglas production function while the Equation (2.4) represents the material balance condition with a plant that has both production processes of electricity generation and pollution abatement.

Table A.1 in the Appendix provides data on the production details of thermal power plants of Andhra Pradesh Power Generating Company (APGENCO) for a period of eight years during the period 1996-2003. There are five thermal plants for APGENCO resulting in 40 observations on each variable for estimating the model. Table A.2 provides estimated pollution loads of SPM, NO_x and SO_2. The descriptive statistics of variables used in estimating Equations (2.3) and (2.4) are given in Table 2.1. The model consisting of a system of two simultaneous equations is estimated using the method of Three Stage Least Squares. Table 2.2 provides the estimates of the parameters of the model. The estimates of coefficients of all the variables in the model are posses the required signs and most of them are significant at the 5 percent level. In the equation explaining the material balance condition, pollution load (z) of a plant is negatively related to the pollution abatement effort (x_4) and positively related to output (y) as expected.

Table 2.1: Descriptive Statistics of Variables Used in Estimation

	Output (Million Units) y	Capital (Lacs) x_1	Wage (Lacs) x_2	Fuel (Lacs) x_3	SPM (thousand tons) z	SPMEN (thousand tons) x_7	SO_2 (thousand tons) x_5	NO_x (thousand tons) x_6
Mean	3984.666	21413.90	2876.656	39760.46	91.9737	1049.108	126.1028	19.873
Standard Deviation	3938.285	21472.95	2608.882	35907.69	97.0023	1096.374	152.4888	39.049

Table 2.2: 3SLS Estimates of Parameters of the Model

Dependent Variable Electricity Output		
Parameter	Variables	Coefficients (t stat)
a_1	Constant	0.571835 (0.904)
a_2	Capital	0.123319*** (4.642)
A_3	Wage	0.098759*** (2.042)
A_4	SPME	0.09653*** (5.033)
A_5	Fuel	0.454351*** (5.613)
A_6	d_1	0.278941*** (4.274)
a_7	d_2	0.568066*** (8.644)
a_8	d_3	-0.246717 (-1.583)
a_9	d_4	-0.868909*** (-4.977)
Adjusted R^2	0.997695	
Dependent Variable SPM (Actual load)		
2nd Equation	Variables	Coefficients
B_1	Constant	-3.618222*** (-3.103)
B_2	SPME	-1.076761*** (-3.283)
B_3	Output	1.845845*** (4.788)
Adjusted R^2	0.477009	

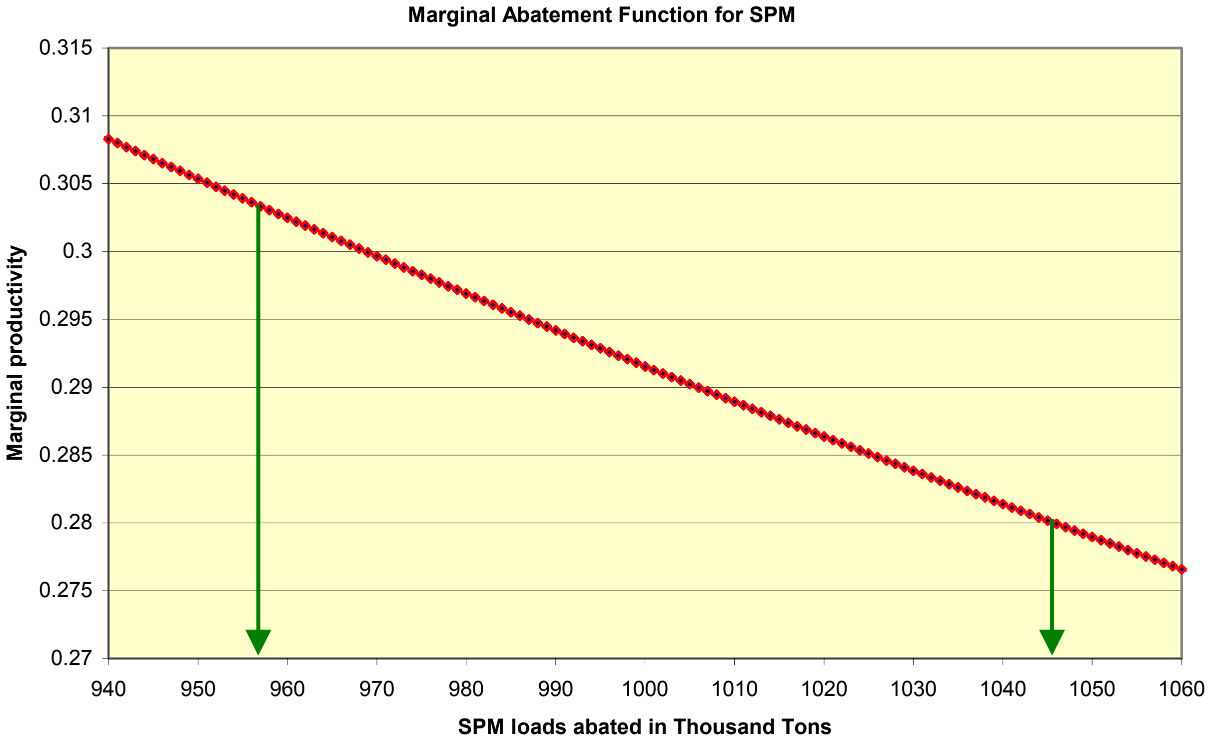
Note: Figures in brackets are t- values. *** shows 1 percent significance level.

Taking the values of all other variables in the production function at their sample mean values, the marginal productivity function of abatement effort (SPMEF) could be derived from the estimated production function as,

$$\partial Output \big/ \partial SPME = 149.6559 \times SPME^{-0.90347}.$$

Graph 1 depicts the marginal productivity curve of the abatement effort. The current electricity tariff (tariff during the year 2002-04) charged by APTRANSCO on an average is Rs 3.68 per unit. The value of the marginal product of SPMEF at its sample mean value is computed as Rs 1117 per ton while it is Rs. 1029 per ton at the pollution abatement required as per the safe standards specified for thermal power generation in India.

Graph 1: The Marginal Productivity Curve of Abatement Effort



III. A Model Describing Production Processes of Firms with Joint Production of Good Output and Pollution

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

$$T = \{(y,x) \in \Re^{M+N}_+ \; y \in P(x)\}. \tag{3.1}$$

The output distance function is defined as,

$$D_O(x,y) = \min\{\lambda > 0 : (y/\lambda) \in P(x)\} \; \forall x \in \Re^N_+. \tag{3.2}$$

Equation (3.2) characterizes the output possibility set by the maximum equi-proportional expansion of all outputs consistent with the technology set (3.1).

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,

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

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 like pollution. The assumption of weak disposability is relevant to describe such production processes. The assumption of weak disposability implies,

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

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 distance function and non-parametric linear programming methods. Fare et al.(1993) presents 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 the assumption that one observed output price is the shadow price. Let y_1 denote the good output and assume that the observed good output price (r_1^0) equals its absolute shadow price (r_1^s) (i.e., for m=1, $r_1^0 = r_1^s$). Fare et al. (1993) have shown that the absolute shadow prices for each observation of undesirable output (m=2,.....,M) can be derived as[3],

$$(r_m^s) = (r_1^0) \bullet \frac{\partial D_0(x,y) / \partial y_m}{\partial D_0(x,y) / \partial y_1}. \tag{3.3}$$

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

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[3] See Fare (1988) for derivation.

under regulation (Fare et al. 1993: 376). Further, the shadow prices do not require the plants to operate on the production frontier.

Estimation Procedure and Data

In order to estimate the shadow prices of pollutants (bad outputs) for thermal power generation in Andhra Pradesh using equation (3.3), the parameters of the output distance function has to be estimated. The trans log functional form[4] used for estimating these functions is given as follows:

$$\ln D_o(x, y) = \alpha_0 + \sum\beta_n \ln x_n + \sum \alpha_m \ln y_m + 1/2\sum\sum \beta_{nn'} (\ln x_n)(\ln x_{n'}) + 1/2 \sum\sum \alpha_{mm'} (\ln y_m)(y_{m'}) + \sum\sum\gamma_{nm}(\ln x_n)(\ln y_m) + \iota_1 d_1 + \iota_2 d_2 + \iota_3 d_3 + \iota_d 4 \qquad (3.4)$$

where x and y are respectively, Nx1 and Mx1 vectors of inputs and outputs. There are three inputs: capital, labour, and energy and three outputs: good output, electricity, and bad outputs, SPM, NO_x , and SO_2, and d_i is the dummy variable representing the plant. A linear programming technique is used to estimate the parameters of a deterministic trans log output distance function (Aigner and Chu 1968). This is accomplished by solving the problem,

$$\max \sum [\ln D_o (x , y) - \ln 1], \qquad (3.5)$$

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

(v) $\sum \alpha_m = 1$

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

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

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

Here the first output is desirable and the rest of (M-1) outputs are undesirable. The objective function minimizes the sum of the deviations of individual observations from

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[4] Many earlier studies for estimating shadow prices of pollutants have used the trnaslog functional form for estimating the output distance function. These include Pitman (1983), Fare et al. (1990), and Coggins and Swinton (1996).

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 maximization of the objective function is done implying the minimization 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) ensure that the desirable output have a non-negative shadow price. The constraints in (iv) restrict that the shadow prices of bad outputs are non-positive, i.e. weak disposability of bad outputs whereas the restrictions in (v) is the derivative property of output distance function with respect to inputs i.e. the derivatives of output distance function with respect to inputs is non-increasing. The constraints in (v) impose homogeneity of degree +1 in outputs (which also ensures that technology satisfies 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.

Table 3.1:Descriptive Statistics of Variables Used in the Estimation of Distance Function

	Electricity generated	Coal	SPMA	SO_2A	NO_XA	CO_2EN
Mean	3984.666	3169.669	91.97375	126.1028	19.87342	6223.227
Std	3938.285	3058.713	97.00221	152.4888	39.04904	6005.38

	Capital	Wage	Fuel	Other inputs
Mean	21413.9	2876.656	39760.46	914.4735
Std	21472.95	2608.882	35907.69	1213.855

Note: A: actual load, EN: load as per engineering norms.

The output distance function described above is estimated by considering electricity as a good output and pollution loads of SPM, NO_x, and SO_2 as bad outputs using data about thermal power generation by APGENCO in Andhra Pradesh state. The data set used is given in Tables A.1 and A.2 in the Appendix. Table 3.1 provides the descriptive statistic of variables used in the an estimation of the distance function. The estimates of the parameters of the distance function are reported in Table 3.2. Using the estimated distance function, the shadow price of a pollutant is estimated in terms of units of good output foregone for one unit reduction in pollution. The computed shadow prices for a representative plant of APGENCO are 11.835, 2.975, and 14.204 thousand units of electricity, respectively per ton reduction of SPM, NO_x, and SO_2. The current electricity tariff for industries in AP is on the average Rs 3.68 per unit. Using this price shadow prices of pollutants could be expressed in rupees as reported in Table 3.3.

3.2: Estimates of Parameters of Output Distance Function

Coefficients of the Output Distance Function Model								
Variables	**Description**	**Coefficients**	**Variables**	**Coefficients**	**Variables**	**Coefficients**	**Variables**	**Coefficients**
y1	**electricity**	1.294	**Y11**	0.059	**y1x3**	-0.405	**y4x1**	-0.002
y2	**SPM**	-0.151	**Y22**	3.04E-04	**y1x4**	0.039	**y4x2**	-0.005
y3	**SO2**	-0.169	**Y33**	-0.004	**y23**	8.05E-04	**y4x3**	-7.90E-04
y4	**NOx**	0.025	**Y44**	-2.47E-04	**y24**	-1.61E-04	**y4x4**	0
x1	**capital**	1.006	**X11**	0.05	**y2x1**	-9.94E-04	**x12**	-0.221
x2	**Wage**	0.149	**X22**	-0.03	**y2x2**	0.015	**x13**	-0.106
x3	**Fuel**	-2.899	**X33**	0.578	**y2x3**	0.029	**x14**	-0.02
x4	**other costs**	0.138	**X44**	0.015	**y2x4**	-0.006	**x23**	0.12
x5	**Time**	0.002	**Y12**	-0.031	**y34**	0.002	**x24**	-0.006
d1	**plant dummy**	0.092	**Y13**	-0.03	**y3x1**	-0.008	**x34**	-0.024
d2	**plant dummy**	-0.066	**Y14**	0.003	**y3x2**	0.009	**Intercept**	4.078
d3	**plant dummy**	0.267	**Y1x1**	0.197	**y3x3**	0.04		
d4	**plant dummy**	0.569	**Y1x2**	0.101	**y3x4**	-0.002		

Description of Variables in the Estimated Distance Function

Names of Variables and their Identification							
Output	Y1	output2	y11	outfuel	y1x3	sofuel	y3x3
SPM	Y2	spm2	y22	outother	y1x4	soother	y3x4
SO_2	Y3	so2	y33	spmso	y23	nocap	y4x1
NO_x	Y4	no2	y44	spmno	y24	nowage	y4x2
Capital	X1	cap2	x11	spmcap	y2x1	nofuel	y4x3
Wage	X2	wage2	x22	spmwage	y2x2	noother	y4x4
Fuel	X3	fuel2	x33	spmfuel	y2x3	capwage	x12
Others	X4	other2	x44	spmother	y2x4	capfuel	x13
Time	X5	outspm	y12	sono	y34	capother	x14
Dummy1	d_1	outso	y13	socap	y3x1	wagefuel	x23
Dummy2	d_2	outno	y14	sowage	y3x2	wageother	x24
Dummy3	d_3	outcap	y1x1			fuelother	x34
Dummy4	d_4	outwage	y1x2				

Table 3.3: Shadow Prices of Pollutants

(Rs, thousand per ton)

Industrial Pollutants	Mean	Standard Deviation
SPM	40.29	73.22
SO_2	10.13	17.57
NO_2	48.35	103.80

IV. Shadow Prices of Pollutants and Pollution Taxes

Estimation of pollution taxes using the Taxes-Standards method requires estimates of the marginal cost of pollution abatement and the data about pollution standards. The shadow prices of pollutants estimated in Section III could be also interpreted as marginal costs of pollution abatement. Using the estimated distance function for thermal power generation in AP, plant specific shadow prices could be calculated. The marginal cost of pollution abatement for each pollutant could be obtained by finding a relationship between the shadow price of the pollutant and pollution load. The marginal cost of pollution abatement of a plant could depend on output, pollution load and plane specific characteristics among others. Specifying this relationship as stochastic, the marginal cost of the pollution abatement function for APGENCO is estimated each for SPM as given in equations (4.1). In this equation, the dependent variables are shadow prices of pollutants (SPMS) and independent variables are pollution concentrations (SPMC), plant specific dummy variables (D_i, i = 1….4) and time. There is a rising marginal cost with respect to pollution reduction as expected.

SPM

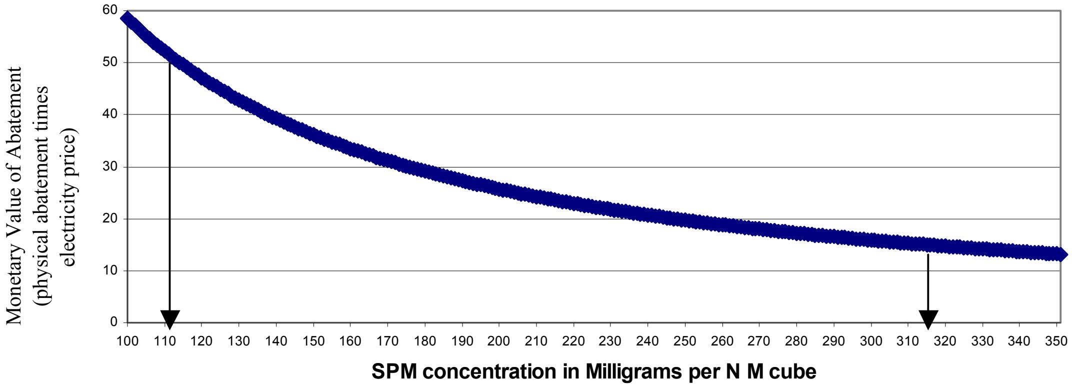
$$\ln SPMS = \underset{(-1.48)}{-1.099}*\ln(OUT) - \underset{(-4.80)}{1.1864}*\ln(SPMC) + \underset{(1.28)}{0.955}*D1 + \underset{(2.51)}{2.326}*D2 - \underset{(-1.45)}{2.463}*D3$$

$$- \underset{(-2.81)}{6.121}*D4 - \underset{(-2.04)}{0.141}*TIME + \underset{(2.97)}{19.300} \qquad (4.1)$$

Adjusted R^2 = 0.82

Figure 4.1 depicts the marginal pollution abatement cost function for SPM. On y-axis marginal cost of abatement and on x-axis SPM concentration are measured.

Figuare 4.1: Abatement Function for SPM concentration



Using the above abatement cost of function of SPM (4.1) and using MINAS Stack Emission Standard of 115 milligrams per Nm^3 the pollution tax of Rs 7.2 thousand per tone of SPM is calculated. The tax rates for other pollutants could be calculated given the emission standards for them.

V. Cost of Environmentally Sustainable Industrial Development and Measurement of Green GDP

There is a cost associated with environmentally sustainable development. The UN methodology of Integrated Environmental and Economic Accounting calls it the maintenance cost or the cost of maintaining the environmental quality at its natural regenerative level. Scientifically, the environmental standards Minimum National Standards, MINAS in India or WHO standards) are supposed to be designed taking into account the natural regenerative capacity of environment media. Therefore, the cost of complying with these standards to the industry may be interpreted as cost of environmentally sustainable industrial development. This cost has to be accounted in the measurement of Green GDP or environmentally corrected net national product (ENNP). The ENNP could be defined as[5],

$$ENNP = C + P_k \Delta K + P_n \Delta N \quad (5.1)$$

where C, ΔK, and ΔN represent respectively, consumption, changes in manmade capital, and natural capital and P_k and P_n are prices of manmade and natural capital.

The first two terms in (5.1) constitute the conventional NNP while the last term accounts for the value of change in natural resource stock (change in environmental quality) due to economic activities during the year. UN methodology suggests the development of physical and monetary accounts of natural capital as satellite accounts to conventional national accounts for estimating $P_n \Delta N$. Time series of physical accounts of ambient quality of atmosphere, and water resources and forest cover has to be developed to estimate ΔN. For example in the case of air pollution studied in this paper, ΔN could be measured as the excess of pollution load of SPM over the pollution load corresponding to

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[5] See Weitzman (1976), Dasgupta and Maler (1998), and Murty and Surender Kumar (2004).

safe ambient standards. In the case of CO_2, ΔN could be simply pollution load generated because it adds to the stock of CO_2 already present in the atmosphere.

Table 5.1: Physical and Monetary Accounts of Air Pollution for APGENCO

	SPM	SO_2	NO_X	CO_2
Load (TT)	372.75	735.66	213.88	35145.36
Shadow Price (Rs. Thousand)	40.29	10.13	48.35	3.381
Cost of Abatement (Rs. Million)	15018.09	7452.30	10341.12	118812.07

Note: Row 2 of Table shows the data of observed emissions of SPM, NO_X, and SO_2 and the emissions estimated using the engineering norms of CO_2.

Different concepts of environmental values and methods of valuation are discussed in the literature. The price of natural capital (P_k) has to be estimated using one of these methods. The UN methodology discusses two concepts: producer values and household values[6]. The producer value is also called maintenance cost or cost of sustainable use of environment for the producer/polluter, the methodology for its estimation is described in sections II and III. Table 3.3 in Section III provides estimates of shadow prices of pollutants for the thermal power generation in AP.

Table 5.1 provides physical and monetary accounts of pollution for AP GENCO during the year 2003. The cost for reducing the pollution levels of SPM, SO_2, and NO_x from the current levels to zero is estimated as Rs 32,811.5 million. The estimated Green Gross State Domestic Product (GGSDP) for AP is Rs 14,68,148.5 million after correcting for this cost. The cost of abatement constitutes 2.18% of the GSDP.

VI. Conclusion

There is a cost associated with the environmentally sustainable industrial development described by the UN methodology of Integrated Environmental and Economic Accounting as the maintenance cost. This cost could be considered as the cost to the industry of complying with the environmental standards fixed taking into account the natural regenerative capacity of the environmental media. Some methods in the theory of production could be used to estimate the maintenance cost.

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[6] See Murty and Surender Kumar (2004).

Two models of describing the technology of polluting firms are presented, one considering pollution as an input in production and another taking pollution as a bad output jointly produced with the good output. Both these models are estimated using the data for thermal power generation in Andhra Pradesh.

The shadow prices of pollutants and cost of pollution abatement are estimated for APGENCO. The maintenance cost or cost of pollution abatement in thermal power generation constitute 2.18 percent of GSDP of Andhra Pradesh. This cost does not account for the cost of CO_2 reductions in thermal power generation that could be very high.

Appendix A:

A.1: Plant wise production details of APGENCO (Rs. Lakhs)

Unit	Year	Electricity generated MU	Capital	Wage	Fuel	Other inputs
KTPS	1996	3414	5208.385	3927.207	35985.44	983.5302
	1997	3520	7063.285	3900.065	39803.5	2031.511
	1998	5162.81	20913.66	4544.283	54207.16	3014.923
	1999	6163.15	49033.02	6240.229	69280.48	731.3237
	2000	7820.37	53011.5	7753.307	79718.48	734.8843
	2001	7647.63	56337.24	8417.165	73595.55	105.7257
	2002	8034.54	64522.83	8173.769	74057.17	2608.398
	2003	8725.53	62232.25	9332.04	67364.44	997.95
VTPS	1996	9858	39745.31	2829.839	86909.66	951.1441
	1997	10274	32645.7	2908.693	95145.25	4141.977
	1998	10357.48	28572.89	3220.471	98994.8	4485.739
	1999	9827.93	36558.48	4625.683	90967.1	2333.007
	2000	9621.53	45695.52	6087.684	93743.62	949.1069
	2001	10198.21	48848.31	5571.023	93664.47	1165.993
	2002	10228.05	45516	5216.052	93119.6	3057.952
	2003	10283.63	45347.05	6146.07	87682.96	894.29
RTS	1996	374	810.6809	606.2961	2870.153	11.81043
	1997	378	562.0845	687.3419	3473.033	325.2862
	1998	400.19	679.6723	899.3132	3264.721	86.47726
	1999	380.37	602.6021	744.3287	4404.694	160.991
	2000	428.7	170.5768	1226.411	4249.887	22.43133
	2001	443.7	628.4514	1201.721	4743.044	65.61657
	2002	425.4	787.0002	1010.138	4050.034	73.96902
	2003	388.67	1213.89	1005.39	3362.1	94.97
NTS	1996	129	342.9276	474.6118	1748.478	18.2849
	1997	111	317.6674	462.5684	2068.884	191.3873
	1998	116.23	390.1964	432.2733	1663.616	77.79813
	1999	97.12	562.4254	522.2251	2050.941	27.44435
	2000	127.94	352.0249	645.5493	2545.542	39.27205
	2001	169.32	639.0464	640.3427	3110.354	18.47977
	2002	156.09	777.0212	582.0524	2435.27	44.34212
	2003	145.9	792.3	645.34	2505.98	38.84
RTPP	1996	1328	11445.55	784.6184	18847.8	4.993026
	1997	2437	16938.22	954.1826	36031.5	2762.625
	1998	2982.75	17035.72	1029.864	41740.42	309.2959
	1999	3365.05	22307.05	1538.045	43942.99	57.71019
	2000	3500.35	33543.13	2626.957	40922.61	1352.182
	2001	3475.37	32336.51	2550.101	47074.21	33.03861
	2002	3400.8	34478.45	2371.642	40835.48	1419.93
	2003	3488.83	37591.55	2531.35	38237.01	154.31

A.2: Plant specific estimates of pollution loads (Thousand tons)

Unit	Year	Coal	SPMA	SO_2A	NOXA	CO_2EN
KTPS	1996	3687.12	134.31	33.59624	2.585589	7239.173
	1997	3344	207.67	245.5119	5.785184	6565.503
	1998	5111.18	355.51	216.3872	13.18501	10035.13
	1999	5731.73	304.18	191.5872	20.30537	11253.5
	2000	7272.94	224.49	170.3936	31.36158	14279.46
	2001	7112.3	108.18	171.5412	129.0677	13964.06
	2002	7873.85	139.25	116.1393	167.2025	15459.27
	2003	8551.02	57.91	143.0931	140.1254	16788.8
VTPS	1996	7196.34	208.37	329.89	5.579009	14129.06
	1997	7191.8	208.4	404.5654	6.071154	14120.15
	1998	7146.66	235.84	292.3674	6.740556	14031.52
	1999	6879.55	185.88	144.4494	5.974439	13507.09
	2000	6735.07	156.38	405.902	10.66144	13223.42
	2001	7138.75	164.25	462.1217	12.9733	14015.99
	2002	7159.64	182.44	484.6852	12.69603	14057.01
	2003	7198.54	105.68	523.9432	60.34528	14133.38
RTS	1996	273.02	7.45	2.171993	0.891	536.0387
	1997	260.82	5.48	10.51516	0.749709	512.0856
	1998	292.14	8	10.51516	0.749709	573.5783
	1999	289.08	3.07	19.20409	6.084177	567.5704
	2000	351.53	2.96	17.01263	5.651653	690.1828
	2001	328.34	0.25	13.52622	1.54136	644.6522
	2002	314.8	4.98	23.68952	11.29369	618.0682
	2003	287.62	4.89	22.51187	10.0586	564.7039
NTS	1996	150.93	38.2	14.27074	0.398	296.3311
	1997	128.76	43.29	15.37624	0.397998	252.8033
	1998	142.96	51.74	17.13027	0.591121	280.6831
	1999	101.98	48.07	6.41343	0.419385	200.2243
	2000	139.45	33.96	24.08714	0.67472	273.7917
	2001	186.25	0.34	35.32626	0.867665	365.6773
	2002	171.7	27.94	34.78036	0.859322	337.1103
	2003	160.49	25.21	32.47018	4.580414	315.1009
RTPP	1996	1049.12	227.66	102.2584	5.339009	2059.809
	1997	1803.38	43.32	27.28485	5.501822	3540.699
	1998	2237.06	31.71	24.02527	6.163619	4392.172
	1999	2523.79	20.02	9.548293	5.727009	4955.129
	2000	2625.26	18.52	24.79577	4.141103	5154.351
	2001	2815.05	16.28	32.30186	4.969152	5526.979
	2002	2380.56	18.14	76.37216	21.82907	4673.915
	2003	2442.18	18.73	112.3512	64.79794	4794.898

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