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Environmental Protection: A Social Choice

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Abstract:
Theoretically, an economic instrument to control pollution is used to change the producer's strategy. The socially optimal level of control is where marginal benefits (MSB) equals the marginal social cost(MSC) of control. But practically it is very difficult to estimate MSB and MSC of pollution control (as pointed out by Coase 1964). In this paper attempt has been made to estimate MSB and MSC by estimating shadow prices from the Cost and Production Functions of Indian Paper Industry. Estimated results make a strong case for economic incentives for environmental protection.

Keywords*: Marginal Social Cost (MSC), Marginal Social Benefits (MSB), Social Choice, Shadow Price, Cost and Production Functions*

1. Introduction

The designing and implementation of market-based instruments (especially the Pigouvian tax) involves huge transaction cost since it requires (therefore Coasen theorem fails) the estimates of marginal damages and abatement cost functions. Thus the externality created by environmental pollution (i.e. water pollution) affects people that may be large in numbers; therefore the cost of estimating the damage function can be very high. Moreover, it is also possible that two locations may have the same pollution concentrations or pollution loads and yet they may differ in terms of the damages. Therefore, an alternative approaches need to be explored.

Baumol and Oates (1988) proposed an alternatives approach consisting the use of a set of standards that serve as targets for environmental quality coupled with fiscal measures and others complementary instruments used as means to attain these standards. They have formulated a cost minimization problem subject to the desired level of waste discharges. They have concluded that tax rates on the wastes should be equal to the shadow price of the pollution constraints, i.e. the marginal social cost of an increase in the stringency of the pollution standard. It was also advocated that tax and standards approach may be looked upon as a procedure that frankly abandons any attempt to obtain extensive information on benefits. It uses the pricing system in the allocation of damage-reducing tasks in an efficient manner that approximates minimization of costs, even without unavailable detailed data on the costs.

The present paper explores briefly the problem of social choice and presents the estimated results of Marginal Social Benefits (MSB) and Marginal Social Costs (MSC) by estimating shadow prices from the cost and production functions of Indian Paper Industry.

The optimal level of environmental protection is a normative question and basically a social decision. Any decision to exploit and or to protect the environment affects a large group of people. Within this large group as well, there is variety of opinion of the best way to exploit/protect the environment. This is the fundamental question of social choice. There are several approaches to makes social decisions. The first is called the Pareto Criterion, which basically amounts to unanimous voting; second is Kaldor-Hicks compensation principle, thirdly social welfare function-representing social choice with a social utility function and Arrow's impossibility choice mechanism ruling out of conversion of individual preference into social preference. The bottom line here is that there is no clear unambiguous way of making social choice. In this study we have made an attempt to calculate the social costs and social benefits of environmental protection at marginal level by estimating cost and production function of Indian paper industry.

2. Estimation of Marginal Social Cost and Benefits (MSC and MSB)

2.1. Estimation of MSC and MSB by Maximization of Production Function

Generally, main objective of a firm is to maximize the profit. However, in the present study, it has been observed that due to adequate demand, the industry may choose maximization of production as its main objective to reap the economies of scale. In order to estimate the marginal social costs and marginal social benefits, the production function of the Indian paper industry has been estimated. Thereafter, the production function is maximized subject to a set of constraints. The shadow price of a resource constraint in a production maximization problem represents the gain in objective function with one unit relaxation in the constraint. Therefore, the shadow price is also the marginal productivity of the respective resource appearing in the constraint. Thus, if we relax the pollution constraint in production maximization problem by one unit (mg/liter), the increase in production is at the cost of increased pollution, which can be taken as a measure of marginal social damage. This increase in production is a private benefit and the increased pollution due to relaxed standard is the social cost. Similarly, if we make the pollution constraint stringent in production maximization problem by one unit (mg/liter), the decrease in production is at a less pollution level, which can be taken as a measure of marginal social benefit. This decrease in production is a private loss and the decreased pollution due to stringent standard is the social benefit.

The Cobb-Douglas type production function has been estimated of the following form:

$Q = b_0\ K^{b1}\ L^{b2}\ RM^{b3}\ VOL^{b4}\ BOD^{b5}\ COD^{b6}$

Where,

Q is the output in Rs., K is capital in million Rs., L is the total wage bill in million Rs., RM is raw material charges in millions, VOL is volume of treated wastewater per day in KL, BOD & COD are in mg/liter. The production function assumes that inputs can be substituted imperfectly which make it convex to the origin. The volume of wastewater, BOD and COD have been taken as resources. Since, the output is directly related with the pollutants. The maximization of the production function subject to the constraints can be stated as a Non-Linear Programming Problem (NLP) as under in general:

$\text{Max } Q = A.\ K^{b1}\ L^{b2}\ RM^{b3}\ VOL^{b4}\ BOD^{b5}\ COD^{b6}$

Subject to

K < Modal Value of Capital (Capital Constraint)
L < Modal Value of Labour (Labour Constraint)
RM < Average Value of Raw Material (RM Constraint)
VOL < Modal Value of wastewater (Water Constraint)
BOD < CPCB standard (Pollution Constraint)
COD < CPCB standard (Pollution Constraint)
K, L, RM, VOL, BOD, COD > 0 (Non-negativity Constraint)

The NLP is specific form can be stated as under:-

$\text{Max } Q = 1.101453.K^{-0.09048}\ L^{0.20584}\ RM^{0.79886}$
$VOL^{0.16992}\ BOD^{-0.30125}\ COD^{0.29832}$

Subject to

K < 1036.11 (Capital Constraint)
L < 190.04 (Labour Constraint)
RM < 282.81 (RM Constraint)
VOL < 30000 (Water Constraint)
BOD <30 (Pollution Constraint)
COD < 350 (Pollution Constraint)
K, L, RM, VOL, BOD, COD > 0 (Non-negativity Constraint)

K, L, RM are in millions and VOL is in KL per day, BOD and COD are in mg per liter. The production function has been estimated from the data of the Indian paper industry as given in Table No. 1.

Unit Code	Q	K	L	RM	VOL	BOD	COD
01	565.95	913.54	11.11	308.64	7000	125	350
02	207.30	82.24	12.50	77.20	2400	788	1952
03	291.33	247.07	20.75	134.40	2784	640	1960
04	133.90	1117.54	22.11	92.71	21600	125	375
05	180.35	383.17	9.00	46.50	7225	467	1890
06	30.20	22.95	2.70	14.50	500	300	250
07	184.00	278.46	7.50	85.00	7500	1200	4000
08	1730.20	10997.40	153.10	331.60	25500	227	988
09	407.50	639.91	23.00	189.00	7500	1400	4500
10	1162.80	11190.32	160.90	454.20	67500	150	700
11	1159.00	507.70	150.60	300.00	41000	205	800
12	1180.40	641.20	103.00	203.70	75000	110	500
13	4055.82	1036.11	192.04	980.90	48000	280	700
14	2557.91	14299.31	227.38	560.46	75000	120	575
15	1701.00	2713.06	21.40	309.20	56600	235	800
16	905.00	31730.00	138.80	400.00	36140	250	600
17	1488.31	1986.14	190.40	146.50	67000	110	700
18	1060.00	1212.77	115.00	365.00	33000	1300	3000

19	1821.00	4007.06	136.00	410.00	36000	617	2884
20	1400.00	1652.57	80.15	440.00	18000	361	1108
21	287.43	77.03	13.54	89.53	4800	67	400

Table 1: Data Used for Estimation of Production Function
Source: Sample Data

The above NLP problem has been solved by developing the Kuhn-Tucker conditions. The shadow prices of respective constraints are given as under:

Constraints	**K**	**L**	**RM**	**VOL**	**COD**	**BOD**
Shadow Prices	-0.034982	3.56512	3.962514	0.11778	0.133358	0.426528

Table 2: The Shadow Prices of Constraints for Production Function (Rs. Millions)
Source: Estimated using sample data

The shadow price of BOD can be interpreted as the loss in the production (in Rs.) if the BOD constraint i.e. CPCB standard is made stringent by 1 mg per liter. This also means that if 1 mg/1 of BOD is further abated the paper industry shall have to forego Rs. 4.26 lakh in terms of decreased turnover. This can be considered as a measure of opportunity cost for the effluent treatment for the paper industry. However, this private loss is the social gain in terms of less pollution and hence a measure of marginal social benefits (MSB). For further analysis, the MSB has been computed with different levels of pollution abatement by changing the pollution constraint (standards) with the same NLP.
Similarly, if BOD constraint is relaxed by one unit, there will be private gain in the production at the cost of increased pollution, which can be taken as a measure of MSC. The computed shadow prices for different level of BOD standard are given in Table 3.

2.2. Estimation of MSC and MSB by Minimization of Cost Function
The industry may also choose to minimize the total cost of production subject to environmental and resource constraints. Baumol and Oates (1988) obtained shadow prices (opportunity and marginal costs) by minimizing cost function of polluting firms subject to given production function and environmental standards as constraints. In this study, the total variable cost function has been estimated to compute marginal cost.

BOD Level	**Shadow Price (in Rs.)**
20	459415
21	455899
22	452434
23	449028
24	445669
25	442360
26	439100
27	435888
28	432723
29	429603
30	426528
31	423496
32	420508
33	417561
34	414656
35	411790
36	408964
37	406177
38	403427
39	400714
40	398038

Table 3: Shadow Prices for Different Level of BOD
Source: Estimated using Sample Data

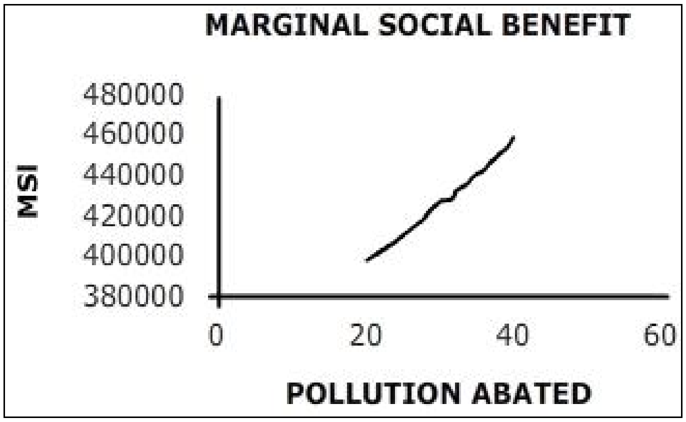

Figure 2: Marginal Social Benefits

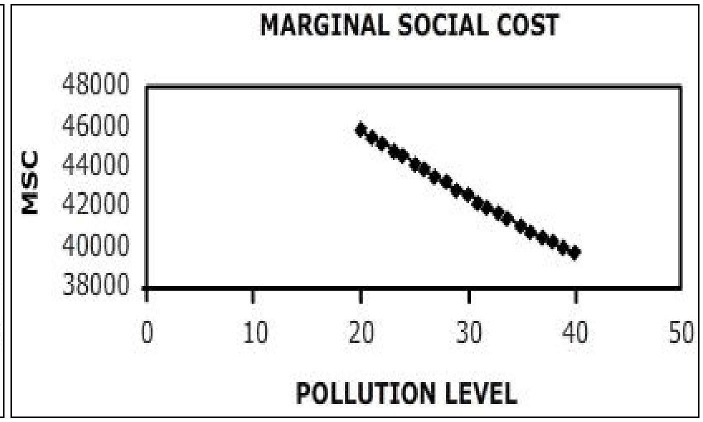

Figure 3: Marginal Social Costs

The total variable cost of production has been taken as a function of output.
Total variable cost of production **TVC = f(Q)**
The specific form of the estimated TVC function is as under:
$TVC = b_0 Qb^1$
The minimization of the TVC function subject to the constraints including targeted level of output, given resources and the environmental standards can be stated as a Non-Linear Programming Problem as under in general:
$Min\ TVC = b_0 Q^{b1}$
Subject to
$Q < b_0 K^{b1} L^{b2} RM^{b3} VOL^{b4} BOD^{b5} COD^{b6}$

K = Modal Value of Capital	(Capital Constraint)
L = Modal Value of Labour	(Labour Constraint)
RM = Average Value of Raw Material	(RM Constraint)
VOL = Modal Value of wastewater	(Water Constraint)
BOD < CPCB standard	(Pollution Constraint)
COD < CPCB standard	(Pollution Constraint)
K, L, RM, VOL, BOD, COD > 0	(Non-negativity Constraint)

The minimization problem in particular is as under:
$Min\ TVC = 1.31903\ Q^{0.81382}$
Subject to
$Q < 1.101453.\ K^{-0.09048} L^{0.20584} RM^{0.79886} VOL^{0.16992} BOD^{-0.30125} COD^{0.29832}$

K = 1036.11	(Capital Constraint)
L = 190.04	(Labour Constraint)
RM = 282.81	(RM Constraint)
VOL = 30000	(Water Constraint)
BOD < 30	(Pollution Constraint)
COD < 350	(Pollution Constraint)
K, L, RM, VOL, BOD, COD > 0	(Non-negativity Constraint)

K, L, RM are in millions and VOL is in KL per day, BOD and COD are in mg per liter. The production function is
TCA = f (VOL, I, E, X, U)
The TVC function has been estimated considering raw material and total wage bill. The above Non-Linear Programming Problem has been solved with the method as explained earlier for production maximization.

Constraints	Q	K	L	RM	VOL	COD	BOD
Shadow Prices	-0.2629	0.0426	-0.5299	1.3894	-0.0028	-0.4163	4.9043

Table 4: The Shadow Prices of Constraints for Cost Function (Rs. millions)
Source: Estimated using sample data

The Table 4 reveals that the shadow price of BOD can be interpreted as the increase in the production cost if the BOD constraint i.e. CPCB standard is made stringent by 1 mg per liter. This also means that if 1 mg/1 of BOD is further abated the paper industry shall have to forego Rs. 49.04 lakh in terms of additional production cost. This is also marginal cost for the effluent treatment for the paper industry. However, this private loss is the social gain in terms of less pollution and hence a measure of marginal social benefits (MSB). Thus, if we relax the pollution constraint in cost minimization problem by one unit (mg/liter), the decrease in production cost is at the cost of increased pollution, thereby is a private benefit and a social cost. It is interesting to note that the private marginal loss is far less (Rs 0.26296 Millions) than the social marginal benefit (Rs. 4.904 Million) with abatement of 1mg/liter of BOD which makes an economic justification of investment in water pollution abatement.

The results of the production maximization and cost minimization problems subject to environmental standards show clearly that marginal private losses of the industry are significantly higher than marginal private benefits in terms of increased costs of forgone output for allocating additional resources for complying with MINAS. This abatement cost structure resulted with CAC regime forces the industry to consider environment as an externality. It has become imperative to introduce the market-based policy instruments to change the mindset of the industry. This analysis has far reaching policy implications which is the subject matter of the next chapter.

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