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Environmental Regulation and Technical Efficiency: A Data Envelopment Analysis for Indian Cement Industry[∂]

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Abstract

The paper deals with the impact of environmental regulation on technical efficiencies of Indian cement producing firms. The effect of environmental regulation on technical efficiencies of firms has been an interesting theme of debate. This paper attempts to derive the technical efficiency scores of Indian Cement producing firms in two scenarios: one in which the firms comply to the set standards by investing additional resources for pollution abatement and the other in which the firms do not take the effort to comply to the set standards by investing resources for pollution abatement. Using establishment level data from Annual Survey of Industries for two years, the most recent data published for 03-04 and a back year for 99-00, the paper attempts to answer a simple question: does imposition of environmental regulation reduce technical efficiencies of firms in an industry? The traditional non-parametric Data Envelopment Analysis framework is modified by substituting free disposability of all outputs by free disposability of good outputs and weak disposability of bad outputs to characterize effective environmental regulation, which ensures that reducing pollution is not costless. For both the years it has been found that the technical efficiency scores of firms under 'effective regulation' scenario are either higher or equal to those derived under 'ineffective regulation' scenario. This results in an average technical efficiency at the industry level in the presence of environmental regulation which can never be lower than that in the absence of environmental regulation. Interestingly, it has also been found that the difference in the efficiency levels in the initial years of implementation of regulation is higher that later, which implies that the extent of efficiency gains from regulation in its initial phase of implementation is higher than those in the following phases.

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Introduction

The effect of regulation on efficiency of firms is a much debated topic in economics and management literature. While some reaction in the behavior of a firm are expected with the imposition of regulation, the final outcome in terms of a gain or loss in efficiency will be determined by a set of factors, important among which are the type of industry the firm belongs to, the market structure in which the firm operates, the firm's objectives, internal characteristics like nature of ownership and size of the firm and also the nature of regulation[1]. Also, the concept of efficiency used for assessing the impact of regulation plays an important role.

Efficiency by its simplest definition refers to the ability of a firm to produce as much output as it can with a set of inputs. With a change in prices of inputs or a shift in technology or otherwise there can result a change in the input mix used by the firm which in turn affects efficiency. When we refer to the firm's ability to produce as much as it can without taking any possible impact of prices of inputs, it is called productive or technical efficiency, whereas when the effect of prices of inputs is taken into consideration while measuring efficiency it is termed as price or allocative efficiency. The overall performance of a firm depends on both the components of efficiency[2]. Often it is found that the effect of regulation on these two components act in opposite directions.

The paper intends to analyse empirically the effect of environmental regulation on the efficiency of firms of cement industry in India. We advocate the use of technical efficiency as an indicator of the performance of a firm for this purpose, a concept originally due to Koopmans (1951) and Debreu (1951) and close to those of internal efficiency (Vickers and Yarrow, 1990) and X-efficiency (Leibenstein 1966 and Leibenstein and Maital 1992). We can rationalise the use of technical efficiency as the performance indicator on the ground that evaluating empirically the overall performance of a firm in terms of fulfilling a multitude of objectives is too ambitious because of the daunting data requirements and limited scope of available techniques to address the problem. As technical efficiency allows for evaluations that are not inconsistent with the multitude of objectives of a firm, the coefficients obtained from estimating the technical efficiencies, even though not complete characterizations of efficiency would not be misleading.

In India the environmental regulations work on Command and Control principles. An effective environmental control of this kind compels firms to abate pollution by investing in pollution abatement technology to avoid closing down of production units for not complying with the set standard. With a series of events in the decade of nineties, noteworthy among which are the Clean Air Act (1990) of US, Rio Summit (1992) and Kyoto Protocol (1997), the issues of pollution control started becoming more relevant all over the world. As a consequence, over the nineties we find environmental laws, policies and regulations shaping up in India to give the nation a competitive edge in the world market. As a result at the industry level the environmental consciousness in terms of complying with pollution standards started to grow over late nineties when the regulations were in the initial phases of implementation. Our choice of time periods for deriving the efficiency scores of firms, one for the year 99-00 to compare with the most recent data published for 03-04, is based on the fact that by 99-00 Central Pollution Control Board in India was successful in sensitizing the industries so that the regulation can be implemented. This can be considered, with not much difference in opinion, as the initial phase of implementation of environmental regulation in India.

For cement, the main air pollutant of concern is the Particulate Matter (PM). The main sources of PM emissions are associated with intermediate and final materials handling and storage (including crushing and grinding of raw materials) and the operation of kiln systems, clinker coolers and mills. Need for particulate collection is driven by both regulation and material recovery. The main pollution prevention and control techniques intend to improve upon handling and storage of materials by better management and design of systems and investments on rotary bag filling machine, electrostatic precipitators, fabric filters, cyclones, etc. A closer look at the existing prevention and control strategies

[1] Kay and Thompson(1986), Hartley, Parker and Martin (1992).

[2] Scherer(1980) takes the viewpoint of social welfare to define what he calls good performance of a firm, which depends on both technical and allocative efficiencies of firms .

of international standards reveals that they aim at fulfilling multiple objectives of material recovery and recycling with pollution abatement.

The main objective of the paper is to see whether there is a significant impact of environmental regulation on efficiency of Indian cement industry. This can be captured in the differences in the efficiency levels of firms in two scenarios, 'effective regulation' and 'no regulation'. The 'effective regulation' scenario will be characterized by one in which the firms abate pollution to avoid closing down whereas a 'no regulation' is virtually the scenario in which the firms choose not to comply with the set pollution standard. In the process we evaluate numerically the performance indicators of firms in cement industry in these two scenarios in terms of technical efficiency. The paper also intends to analyse the behavior of the intensity of this impact of environmental regulation on efficiency over time. That is to find out whether the difference in average efficiency levels in the two scenarios increases or decreases over time. This enables us to understand whether the extent of the impact of environmental regulation on efficiency is more pronounced in its initial phases of implementation than that in the latter.

The paper employs a non-parametric data envelopment analysis technique for computing the efficiency scores as an output measure in two scenarios, one with regulation and the other without regulation. Presence of environmental regulation is characterized by imposing the constraint of weak disposability of bad outputs and free disposability of good outputs (which ensures that reduction of bad output is not a costless affair) in the conventional linear programming input-output framework with free disposability of all outputs. Unit level data published by Annual Survey of Industries (ASI), Central Statistical Organisation for the most recent publication of 03-04 and a back year 99-00 are used for the analysis. For both the years the technical efficiency scores of firms are derived in the two scenarios mentioned above. The main result suggests that for both the years the technical efficiency scores of the firms in the 'effective regulation' scenario are either higher or equal to those in the 'no regulation' scenario. Thus the average technical efficiency of the industry as a whole records a rise with effective environmental regulation on cement manufacturing. Also the difference in the average technical efficiency scores in the two scenarios diminishes over time. For 99-00 there is an increase in the average technical efficiency of cement firms by 8 percentage points whereas in 03-04 the recorded increase is of 2 percentage points only. This implies that the extent of gains in terms of efficiency is higher in the initial phase of implementation of regulation and it gradually decreases over time.

The paper is organized as follows:

Section 2 gives the motivation and perspective of the present paper in the light of prior work done in this area. Section 3 gives the details of the sources of data collected for the analysis. Section 4 elaborates on the methodology used for the present research. Section 5 summarises the results. Section 6 gives the concluding remarks.

2. Prior work

This section would attempt to bring together two strands of literature, one that focuses on the relationship between efficiency and regulation in general and the other that concerns with efficiency of industries under environmental controls. The main objective would be to discover the gaps in the literature which can justify the need for the present analysis.

In general, regulation consists of measures to control price, sale, rate of returns, production decisions of firms with a view to restrict individual decision making that ignores public interest. The first rigorous theoretical framework on the impact of regulation on the performance of a production unit is given in the classic Averech-Johnson (1962) paper focuses on the suboptimal allocation of economic resources that can be the result of imposition of a rate of return constraint for price control by the regulatory authority. Since the rate of factor substitution is not equated to the ratio of factor costs, the firm becomes inefficient in the sense that social cost is not minimized at the output level chosen by the firm. The problem is set in the context of a monopoly firm seeking to maximize profits and the model is applied successfully to US telephone and telegraph industries. However this theoretical construction deals with overall efficiency of the firm taking into account the price effects and does not concentrate on technical efficiency.

Recent theoretical literature also attempts to analyse the effect of regulation on efficiency in a specific perspective by classifying firms according to the nature of ownership and then determining the relationship between efficiency and regulation. If we compare regulated and unregulated private firms, theoretical literature consistently predicts a lower efficiency level for a regulated firm. The most cited example is the rate of return regulation in cases of utilities. If the comparison is between a private regulated firm and a public regulated firm, we come across three results which are worth reporting in the literature. They are: Shapiro and Willig (1990) result which shows that under quite general conditions there is no difference in the performance of a public enterprise and a private company subject to an optimally designed regulatory and tax scheme; Pint (1991) which, in a slightly different setting with asymmetric information, argues that both private and public regulated firms are inefficient but in a different way, the private firm on account of using more capital than specified by the optimal level and the public enterprise for using relatively more labour than specified by the optimal; Laffont and Tirole (1990) result which states that the technical efficiency, measured by managerial effort, is lower in a regulated private firm than a regulated public enterprise.

From the empirical literature it is quite evident that the relation between regulation and efficiency is not necessarily monotonic. While there have been studies in support of the hypothesis that a firm under heavy regulation is bound to be less efficient than that under complete deregulation[3], it is not obvious that in the process of deregulation efficiency always increases. Three studies are worth reporting which has shown that productive efficiency can fall in the process of deregulation. They are: Sickles and Streitweiser (1991), in the context of US national gas pipeline industry which experienced an unfinished process of deregulation, which concludes that there is a declining trend in technical efficiency in the industry for the period in which major deregulatory measures were implemented; Barla and Perelman (1989) in the context of European and North American airlines industry which indicates to an outcome of similar nature; Fecher and Pestieau (1993) in the context of financial services of OECD countries which observes that regulation makes the sector more technically efficient.

The above discussion makes it clear that while regulation constraining the rate of return of a firm is bound to reduce its overall efficiency theoretically, empirical evidence on the effect of regulation on technical efficiencies of firms is somewhat ambiguous. When the production units are categorized according to type of ownership to study the effect of regulation on performance indicators, even theoretical studies comparing the performance of public and private firms subject to regulatory measures come to diverse conclusions.

The literature analyzing the effect of environmental regulation on productive efficiency has given enough evidence in support of both sides of the story. While the Porter Hypothesis (Porter et al 1995) emphasizes on the ‘Win Win’ opportunities in terms of environmental regulation which ensures that pollution can be reduced with an increase in productivity, Palmer et al (1995) criticizes this view on the ground that such opportunities are matter of chances. There have been studies on empirically estimating the relationship between efficiency and environmental regulation following two main approaches. One approach is to account for the effect of pollution abatement cost on total factor productivity (Gallop and Roberts1983, Barbara and McConnel 1990, Gray and Shadbegian 1995). The second approach is that of computing efficiency scores and observing the differences with and without environmental regulation (Boyd and McClelland 1999, Murty and Kumar 2003).

Boyd and McClelland (1999) have established empirical evidence in favor of Porter Hypothesis for US paper plants using input distance functions and hyperbolic measures of efficiency. Murty and Kumar (2003) find some evidence in favor of Porter Hypothesis for water pollution in sugar industry in India which also uses a parametric input distance function.

The present paper maintains the track of the second approach and intends to see the effect of environmental regulation on technical efficiency of cement producing firms in India. A close look at the literature on efficiencies of Indian industries reveals that while some work has been done on estimation of technical efficiency of manufacturing sector as a whole (Coondoo and Neogi, 1998),

[3] Good, Nadiri and Sickles (1991) is one good example

textile industry (Bhandari and Maiti 2006), engineering industry (Goldar et al 2004), washing soap (Goldar1985), small scale industries (Goldar1988, Bhawani1991), none of them has attempted to study the effect of regulation on efficiencies of firms. Almost all of them intend to find out the nature of relationship between the size, age and ownership patterns of firms to their efficiency levels but empirical analysis of the results of regulation on efficiency of industries is one area which is yet to be explored for Indian industries. The present paper is an attempt to fill up this gap. The main objective would be to analyse the impact of environmental regulation on technical efficiency of Indian cement industry. We would like to answer the simple question: Does imposition of environmental regulation reduces the efficiency levels of firms?

3. Data

In this section we would describe the data collected for estimating the technical efficiency scores of the firms in the Indian cement industry. We have used establishment level data published by Annual Survey of Industries (ASI), Central Statistical Organisation, Industrial Statistics Wing, India. The dataset covers the registered manufacturing units in India up to the classification of 5-digit level according to National Industrial Classification (NIC) of 1997-98.

For this analysis we have used this dataset for the most recent year 2003-04 and also 1999-00. ASI divides the entire frame into Census and Sample sectors depending upon the method of collecting data. The Census sector, for major states, represents units having more than 200 workers, which are covered fully whereas otherwise the data is collected on the basis of stratified sampling with properly assigned values of multipliers to the representative units.

We have taken cement industry for our analysis as cement is one of the most polluting industries in India. We find that three industries viz. Manufacture of cement in the form of clinkers (5-digit code 26941), Manufacture of portland cement, aluminous cement, slag cement and similar hydraulic cement, except in the form of clinkers (5-digit code 26942), and Manufacture of asbestos cement (5-digit code 26943), can be taken from the NIC 98 five-digit classification. However out of 68 firms taken for the analysis for 99-00 only one firm belongs to 26941 and two firms belong to 26943, the remaining 65 firms belong to 26942 whereas for 03-04 out of 243 firms, nine firms belong to 26941, six to 26943 and the remaining 228 to 26942. So the analysis is mainly confined to portland cement.

Once the industries are matched, variables of our interest can be extracted from different blocks of the dataset. The data is collected according to 10 blocks (A-J), each block giving a set of variables for each firm. Table 1 below gives the heading of each block.

Table 1 Block Descriptions

Block	Heading
A	Identification
B	Ownership, Type of Organisation, etc
C	Fixed Assets
D	Working Capital and Loans
E	Employment and Labour Cost
F	Other Expenses
G	Other Receipts
H	Indigenous Input Items
I	Imported Inputs
J	Products and Bi-products

The data-notes consist of a data dissemination structure, questionnaires for each block , a tabulation programs , and a set of codes used in the data for industries (5-digit codes were used in the paper), states and union territories , rural or urban classification (rural1, urban 2) status of units (open, closed, etc), types of organization and types of ownership . ASICC codes for the items consumed and produced in the process, codes of units of measurement of the items consumed and produced are also given. The codes, which are not disclosed, are those of the districts and firm identifications.

The data is collected as strings of numbers of a fixed width of 152 characters. Each block has a separate structure for dissemination of variables. The data is formatted according to the data dissemination structure using SPSS program. The variables of interest are extracted by writing appropriate programs, after careful scrutiny and understanding of the questionnaires circulated to the firms by CSO and the tabulation program.

For our analysis we have used extensively Blocks A, B, C, D, E, H, and J. From Block A the first round of screening gives the list of firms which are in operation. For this we selected the units which have positive total number of working days and cost. Though a variable stating the status of unit is present, it was found that some of the closed units have reported positive number of working days and positive costs of production. On verification it was found that those units were not closed for the whole accounting year, though reported as closed. The unit identification codes after this screening with the associated state codes and rural urban codes were collected from this block. Multiplier values given for each unit (or the scheme code) gives the information regarding whether the units belong to the census sector or is a member of the sample stratified during data collection. The variables of our interest were later adjusted multiplying by the value of the multiplier to get their appropriate estimates for the firms belonging to the sample sector.

Block B gives the type of ownership of the firms. We have six categories ranging from purely public to purely private firms, like central government (code 1), state or local government (code 2), central and state or local government (code3), joint sector public (code 4), joint sector private (code 5) and private (code 6). In the sample of 68 firms which are finally used only 13 firms are there in code 1 to code 5 category, rest are all privately owned firms.

Block C gives us two variables of our interest, size and the values of net fixed capital assets (FCAPM) for each unit. Size is constructed as a string variable according to the gross values of investment in plant and machinery of the firm. If it exceeds 3 Crores, the Size is 'L', otherwise the Size is 'S'. (This variable differentiates firms belonging to large and medium sectors and small sector according to limits specified in 1999-2000). In our sample only 3 firms had the investment limits to be qualified as small firms, rest are all large firms. Due to lack of variation in our sample in terms of size, we do not include this variable in our final analysis.

FCAPM (expressed in Rs) is defined as the net value of fixed assets. From Block D the values of net working capital (expressed in Rs) defined as the difference between total current assets and total current liabilities, are extracted as the variable WCAPM. For both FCAPM and WCAPM, average of the opening and the closing balance of the units if both were reported and either of the two (whichever has been reported) if both were not reported adjusted by the multiplier are taken.

From Block E the figures for total mandays generated are extracted as the variable MDAYSM.

From Block H the figures for consumption of inputs are extracted. This block reports quantity consumption (expressed in quantity units) and purchase value of basic and non basic items used in the production process .with their item codes and unit codes. We take the purchase value for all these items as the variable MAT to capture the expenditure of the firms on account of input use. Among the basic inputs they record five major material inputs used for the production and all other basic inputs clubbed together as another category. In the non-basic category they record expenditure on chemicals, packing items, consumption of energy inputs like Coal, Electricity (manufactured by the unit and bought from outside), petrol, diesel, oil, lubricants, and other fuels consumed and value of consumable store.

From Block J we have extracted the output production and sales figures (expressed in quantity units) for cement and total ex-factory value of products and bi-products for each firm (expressed in Rs). The records consider ten major products and by-products manufactured by a firm with their production and sales figures. Given their respective item codes and unit codes we choose only to take the codes related to cement and record the quantity manufacture and sales data. We need this to generate the pollution figures from the emission coefficients given by Central Pollution Control Board for PM emission in cement industry. These coefficients are given on the basis of standard production practices in India with and without abatement technologies. Two sets of pollution estimates are generated, one using the coefficients without compliance facilities and one with the coefficients with compliance facilities with standard best practice technology.

The list of variables and their definitions are given below:

EXFAC: Ex-factory value of all the products and bi-products produced by a cement firm (Rs)

QMANM: Quantity of cement produced by a firm (tonnes)

PM: particulate matter emitted from a firm without the use of control technologies (tonnes)

PMA: particulate matter emitted from a firm with the use of control technologies (tonnes)

MAT: purchase value of all basic and non-basic inputs used for production (Rs)

LAB: total mandays generated

FCAPM: Net value of fixed assets (Rs)

WCAPM: Net value of current assets (Rs)

The descriptive statistics of the variables used to estimate DEA models for cement industry for two years are given in Table 2.

Table 2: Descriptive Statistics of Variables Used in the Models

	MAT	LAB	FCAPM	WCAPM	QMANM	EXFAC	PM	PMA
Year	**1999-00**							
N	69	68	68	68	70	68	68	68
Mean	654595319.79	226788.48	12720591284.31	225470961.94	1192073.41	31850105383.20	255655.27	856.94
Median	542106170.00	214976.50	5213137460.00	106414000.00	650163.12	793598353.00	170522.56	571.58
Std. Deviation	622452321.10	179629.81	17476965541.10	291142990.97	1373190.51	254258489585.13	272161.64	912.27
Minimum	68.00	1179.00	.00	.00	.00	429352.00	85.20	.29
Maximum	2177960187.00	865452.00	77315616165.00	1624460000.00	5442634.78	2097670127000.00	980840.88	3287.73
Year	**2003-04**							
N	243	243	243	243	243	243	243	243
Mean	358427553.10	84105.53	628622311.78	32004600.34	2293501.90	557993471.78	365798.48	1226.14
Median	20718936.00	12550.00	13713300.00	1271100.00	12324.000	23902576.00	4370.82	14.65
Std. Deviation	685929111.288	125988.10	1524775868.250	210056859.75	22206953.09	1046768680.55	3629114.18	12164.62
Minimum	0	0	.00	-809128008.00	2.00	19362.00	.00	.00
Maximum	4444844494	593493	12485500000.00	2029313375.00	309027441.00	6265655950.00	56544310.00	189534.00

4. Methodology

As discussed earlier we have used DEA for computing the technical efficiency scores of the cement manufacturing firms in India. In this section we will first give an outline of the basic principle on which the methods for computation of technical efficiency scores are based. This will be followed by the formulation of our specific problem as a formal DEA model.

The basic principle of productive efficiency analysis followed in the literature can be summarized in a one input (x), one output (y) activity with reference to Figure1.

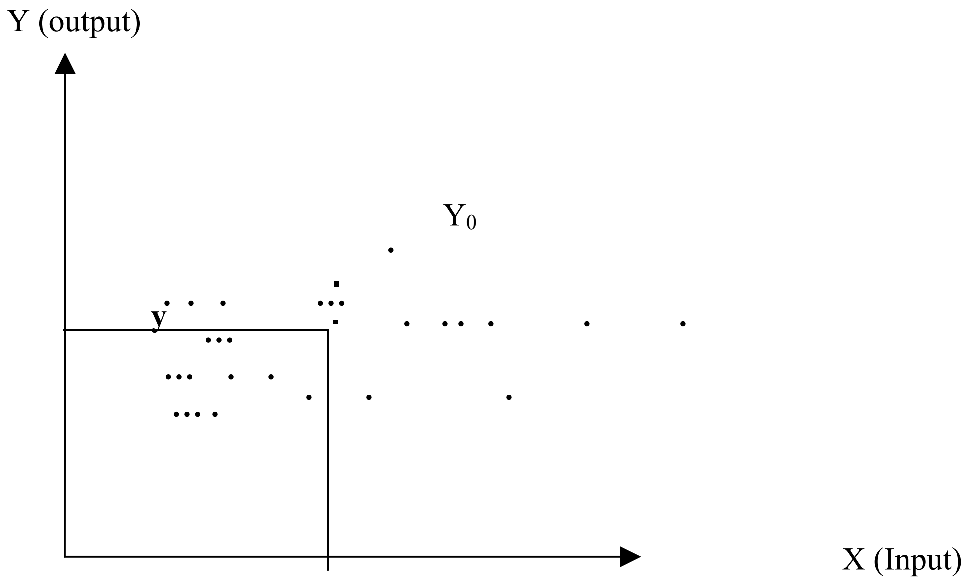

Figure 1

The scatter diagram in Figure 1 represents a set Y_0 of statistical data available on inputs and outputs. Measuring efficiency with this kind of a dataset requires first to determine the boundary of the unknown production set Y and then to measure the distance between any observed point in Y_0 and the boundary of Y.

It is the task of the efficiency analyst to construct the unknown production set that suits his purpose the best. The boundary of this set can be determined using parametric or non-parametric techniques. Parametric determination of this boundary in Aigner and Chu (1968) suggests that the boundary can be represented by a production function with a chosen functional form. The parameters of this function are determined in such a way that the observed input-output combinations lie on or below the graph of the function. In Figure 2, AB can be a possible production function fitted to the data set following parametric estimation.

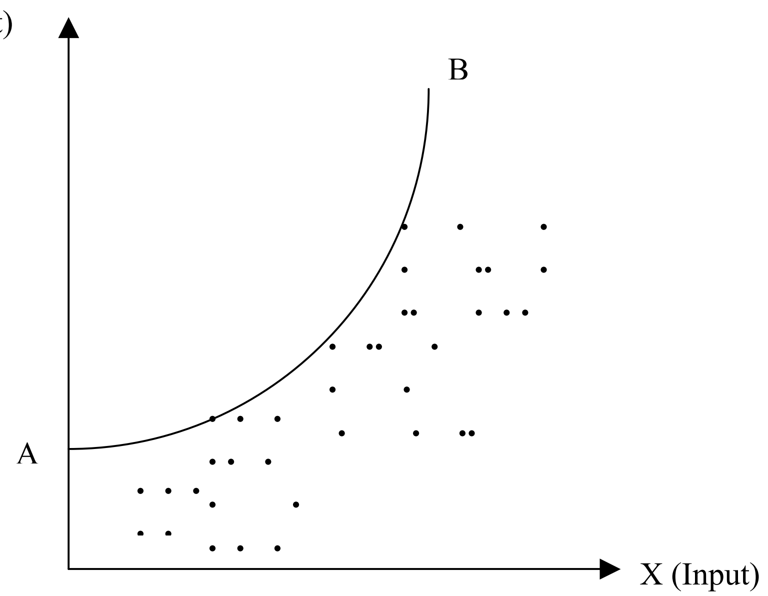

Figure 2

The non-parametric method of constructing the reference set rests on a set of assumptions regarding the relationship between the elements of the constructed set and the statistical observations. The elements expected to belong to the reference set have to satisfy certain characteristics. These set of characteristics defines one non-parametric methodology and differentiates it from the other. The standard models of Data Envelopment Analysis (CCR 1962, BCC 1984) are based on the following set of assumptions:

First, the reference set should contain all the observed production plans;

Second, the free disposal hull postulate must be satisfied which means either outputs or inputs or both are freely disposable ie any unobserved production plan with output levels equal to or lower than those of some observed production plan and more of at least one input and/or input levels equal to or higher than those of some observed production plan and less of at least one output will belong to the reference technology set;

Third, convexity which means any unobserved production plan that is a convex combination of some observed production plans will be contained in the reference set.

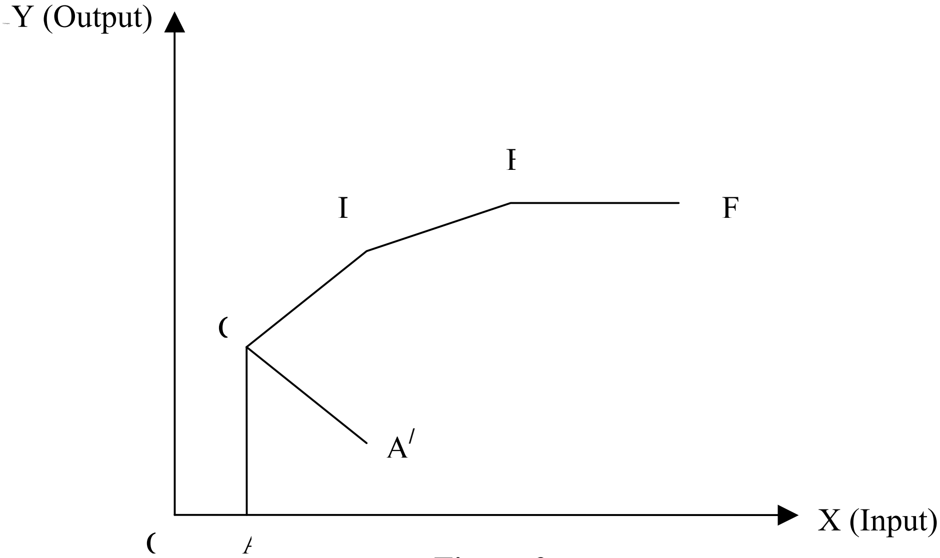

Figure 3

In Figure 3, ACDEF is a possible frontier under DEA. We follow the DEA (BCC 1984) technique to calculate the efficiency scores of firms in the cement industry. In our endeavor to arrive at efficiency scores of firms under environmental regulation we modify the model by incorporating weak disposability of bad outputs in this standard model instead of free disposability of outputs in general. By weak disposability of bad output we ensure that pollution can be reduced without reducing the production of good output by using additional resources. This assumption alters the 'disposal hull'; we get a weak disposal hull instead which is more restrictive than the free disposal hull. The other assumptions of the standard framework on DEA being retained, A$^{/}$CDEF (Figure 3) can be considered as a possible frontier under weak disposability. The details of the construction of the problem and the computation methods are provided below.

The Problem

The concept of frontier, as discussed above, can be estimated using parametric or non-parametric methods. Parametric estimation involves stochastic frontier models or models like distance functions based on programming techniques, which presume a functional form of the frontier. The non parametric models are computed using linear or integer programming. The computation of DEA is based on linear programming method. The computer solves as many linear Programs as there are firms. In what follows we will elaborate the steps involved in the formulation of a problem in the DEA framework

In the traditional DEA model, production technology with the following properties is hypothesized:

i) The production possibility set is convex, ie if (x^0, y^0) and (x^1, y^1) are both feasible input-output bundles then $(x^/, y^/)$ is also a feasible bundle where $x^/ = \lambda x^0 + (1-\lambda) x^1$, $y^/ = \lambda y^0 + (1-\lambda) y^1$, $0 \le \lambda \le 1$.

ii) Inputs and outputs are freely disposable ie if $(x, y) \in T$ then $(x^/, y) \in T$ when $x^/ \ge x$ and $(x, y^/) \in T$ when $y^/ \le y$.

iii) When a sample of input-output bundles (x^i, y^i) is observed for N firms, N=1,……,N, we assume further that $(x^i, y^i) \in T$ for i=1,2,…..,,N.

iv) The technology satisfies variable returns to scale.

We select $T^v = \{(x,y) : x \ge \Sigma\lambda_j x^j ;\ y \le \Sigma\lambda_j y^j ;\ \Sigma\lambda_j = 1;\ \lambda_j \ge 0, j=1(1)n\}$, the smallest of all the sets satisfying assumptions (i) - (iv). This is the inner approximation of the underlying technology set.

Let there be N firms each producing m outputs from n inputs. Firm t uses input bundle $x^t = (x_{1t},\ldots,x_{nt})$ to produce output bundle $y^t = (y_{1t},\ldots,y_{nt})$. We use vector of virtual prices of inputs and outputs and get the average productivity of firm t as :

$AP_t = \dfrac{\sum_{r=1}^{m} v_{rt} y_{rt}}{\sum_{i=1}^{n} u_{it} x_{it}}$, where $u^t = (u_{1t},\ldots,u_{nt})$ and $v^t = (v_{1t},\ldots,v_{nt})$ are the virtual price vectors for inputs and outputs respectively.

We choose the vector of shadow prices that maximizes AP_j

sub to $AP_j \le 1$ (j=1,….,t,…N)

and $u_{it} \ge 0$, (i=1,….,n); $v_{rt} \ge 0$ (r=1,….,m).

This is a linear fractional functional programming model. A simple solution of this problem has been provided in Charnes and Cooper (1962). By suitable transformation and scaling of variables followed by normalization converts it to a linear programming problem the dual of which can be written as an input minimization problem as follows:

$$\begin{aligned}
&Min \quad \theta \\
&st \quad \sum_j \mu_j x^j \le \theta x^j \\
&\sum_j \mu_j y^j \ge y^j \\
&\sum_j \mu_j = 1 \\
&\mu_j \ge 0
\end{aligned}$$

Let $(\Theta^*, \mu^*_{1,\ldots\ldots\ldots,} \mu^*_N)$ be the optimal solution. Define $x^{t}{}_{*} = \Theta^* x^t$. Then $(x^{t}{}_{*}, y^t)$ is the efficient input oriented radial projection of (x^t, y^t) onto the frontier and the input oriented technical efficiency of the t th firm is given by Θ^*.

Define $\Phi = 1/\Theta$ and $\lambda_j = \mu_j / \Theta$. Then minimization of Θ is equivalent to maximization of Φ. In terms of the redefined variables the output oriented technical efficiency measures can be obtained by solving the following LP problem as Model 1:

$$\begin{aligned} &Max \quad \phi \\ &st \sum_j \lambda_j y^j \geq \phi y^j \\ &\sum_j \lambda_j x^j \leq x^j \\ &\sum_j \lambda_j = 1 \\ &\lambda_j \geq 0 \end{aligned}$$

We would use this output version of technical efficiency for our analysis where the technical efficiency scores of each firm will be the reciprocal of the optimal value of the objective function ie $1/\Phi^*$.

We modify the standard model for output-oriented technical efficiency by replacing the assumption of 'free disposability of all outputs' by 'free disposability of good output and weak disposability of the bad output'. A different production possibility set (T^v_w) which is the weak disposal hull, associated with this version of the formulation can be written as below as:

$T^v_w=\{(x,y) : x\geq \Sigma\lambda_j x^j ;\ y = \alpha\, \Sigma\lambda_j y^j ;\ \Sigma\lambda_j =1;\ \lambda_j\geq 0,\ 0 \leq \alpha \leq 1;\ j=1(1)n\}$.[4]

A modification of Model 1 can be given below as Model 2:

$$\begin{aligned} &Max \quad \phi \\ &st \sum_j \lambda_j y_g^j \geq \phi y_g^j \\ &\sum_j \lambda_j y_b^j = \alpha\phi\, y_b^j \\ &\sum_j \lambda_j x^j \leq x^j \\ &\sum_j \lambda_j = 1 \\ &\lambda_j \geq 0 \\ &0 \leq \alpha \leq 1 \end{aligned}$$

Here we differentiate two categories of outputs viz y_g, the good output and y_b, the bad output and have two sets of constraints, one for each, in the optimization exercise. Weak disposability of bad output implies that now the production possibilities are such that it does not automatically includes any level of bad output which is below an achievable level of bad output in the production set. That is to say, in order to reduce bad output the firm needs to use additional resources. This also signifies the efforts of firms for compliance with regulation in the sense that only in the presence of regulation the firms are forced to reduce pollution by using control technologies to avoid shut down of their unit. Mathematically, by incorporating the bad output constraint as equality in an LPP we are actually allowing our model to have negative shadow prices for the bad outputs, which is compatible with an economic model of pollution control.

5. Results

We solve two sets of models, one with free disposability of outputs and the other with weak disposability of bad output and free disposability of good output, for each year 99-00 and 03-04 separately. We take one good output which is the EXFAC variable as the total ex-factory value of

[4] We finally solve the model setting α=1, as it can be shown that this does not alter the optimal value of the objective function (Fare *et al*1987).

products and by-products in a cement manufacturing firm. The bad output is the PM emission of each firm as obtained by engineering estimates calculated on the basis of quantity of cement manufactured in the firm, in the presence (PMA) and absence (PM) of control devices. We use PM and EXFAC as freely disposable and work out the model which gives us the technical efficiency scores in a situation where the firms do not take any effort to comply with the regulatory rules. In the model with weak disposability we use PMA as weakly disposable and EXFAC as freely disposable. This gives us the results of the scenario where regulation is effective, ie firms are diverting resources for pollution abatement. Both the models have four input variables viz. MAT, LAB, FCAP, WCAP.

Table 3 below summarises the results of the two models in each of the two time periods. We find that for both the time periods, the efficiency scores in the weak disposability model are either higher or equal to those in the free disposability model. In 99-00 the median value for the technical efficiency scores in the weak disposability model is 81% whereas that in the free disposability model is 73%. Thus, if we take the median value, we can say that on an average by increasing output levels by 19% a firm can reach the frontier if all the firms take initiatives to comply to the environmental standards whereas if none of them invest in abatement technology the average expansion in output required to reach the frontier is 27%. If we take the mean, the industry records an average efficiency score of 76% in the model where regulation is effective whereas that recorded for the model where none of the firms are complying with the standard is 68%. It has been found that the difference in the means for the two models is significant at 1% level. This indicates that in the year 99-00, there can be an increase in the average level of productive efficiency for cement industry by 8% if cement firms are ready to comply with the environmental standard.

For 03-04, the median value for the technical efficiency scores in the weak disposability model is 64% whereas that in the free disposability model is 61%. On the basis of these median values, we can say that on an average by increasing output levels by 36% a firm can reach the frontier if all the firms take initiatives to comply to the environmental standards whereas if none of them invest in abatement technology the average expansion in output required to reach the frontier is 39%. If we take the mean, the industry records an average efficiency score of 65% in the model where regulation is effective whereas that recorded for the model where none of the firms are complying with the standard is 63%. It has been found that the difference in the two means is significant at 1% level. On the basis of the mean values in the two models for the year 03-04, we can say that there can be an increase in the average level of productive efficiency for cement industry by 2% if cement firms are ready to comply with the environmental standard.

Table 3: Descriptive Statistics of the Efficiency Scores Derived for Two Models

	EFFICIENCY SCORES WEAK DISPOSABILITY MODEL 2		EFFICIENCY SCORES FREE DISPOSABILITY MODEL 1		DIFFERENCE IN EFFICIENCY SCORES MODEL2~MODEL 1	
Year	99-00	03-04	99-00	03-04	99-00	03-04
N	68	243	68	243	68	243
Mean	.76	.65	.68	.63	.08≠	.02≠
Median	.81	.64	.73	.61	.08	.03
Std. Deviation	.30	.27	.29	.26		
≠ Significant at 1% level						

The main findings can be summarized as follows:

First, for both the time periods the average measures of efficiency scores are higher in the ‘effective regulation’ scenario where the firms comply with the set standards than those in the ‘ineffective regulation’ scenario. Second, using either of the measures of central tendency, the average gains in the efficiency level is higher in the year 99-00 than those in the year 03-04. This clearly implies that for Indian Cement producing firms there exists an incentive to invest in pollution control technologies and comply with the set pollution standards by abating pollution as it can induce an increase in the technical efficiency levels of firms. However the magnitude of gains in efficiency levels is higher in the initial phase of environmental regulation than in the following phases.

6. Concluding Remarks

The paper intends to see whether environmental regulation in India has the potential to induce higher efficiency levels for industries. In India, the environmental regulations are based on command and control principles under which standards for specific pollutants for different industries are set, violation of which leads to closing down of the production units. The producing unit has to qualify for a clearance issued by the monitoring authority, ie the Pollution Control Board. In such a set up there is a lot of scope for illegal negotiations between the producing unit and the administrative officials of the Pollution Control Boards which is often cited as the cause for poor environmental quality in India. The firms are, on paper, shown to comply with standards, which is actually not the case.

The present analysis shows that there exists an incentive for the cement producing firms to adopt abatement technologies and comply with the standards as the process leads to a gain in efficiency. This is because the pollution control technologies in cement manufacturing are a combination of better management strategies to check loss and leakages in production, better recycling procedures and prevention technologies. So, use of control technologies lead to better material recovery, which contributes to enable the firms to achieve higher productive efficiency.

The paper employs a non-parametric data envelopment technique to derive the technical efficiency scores of Indian cement manufacturing firms in two scenarios, one in which all the firms would take initiatives to abate pollution and the other in which no firms take initiatives to abate pollution. Using data for two time periods 99-00 and 03-04 we find that the scenario in which firms choose to obey regulation ensures them relatively higher efficiency scores than in the other scenario for both the years. On an average the industry can gain in terms of productive efficiency by 8 percentage points in 99-00 and 2 percentage points in 03-04, which is found to be statistically significant for both the years. This clearly indicates that cement producing firms in India have an incentive for opting to comply with the environmental standards set by the regulation for their own benefits. However the magnitude of gains in efficiency levels is found to decrease over time. They are more pronounced in the initial phase of implementation of regulation than in the subsequent phases.

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