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Impact of Environmental Regulation on Technical Efficiency: A Study of Chemical Industry in and around Mumbai

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Introduction

- Pollution is not freely disposable due to environmental regulation
- Opportunity cost of reducing pollution for firms?
- Firms have three options:

  (i) Only make abatement expenditures (loss in output)

  (ii) Make both productivity enhancing and abatement expenditures,

  (iii) Only make productivity-enhancing expenditures (ignore pollution/ sustainable development)
- Hence it is essential to estimate cost of environmental regulation for firms

Objective of the Study

The objective of this study is three-pronged:

- To study the behaviour of polluting firms in the study area
- To find out how firms respond to such environmental regulations, and finally
- The impact such regulations have on the technical efficiency of such polluting firms: Does a win-win situation in current context exist?

Review of Literature

- Polluting firms jointly produce two types of output: good and bad
- Underlying assumption in conventional theory: free disposal of bad output
- In the current situation, unwanted outputs are not freely disposable [Shephard, (1970)]
- Conventional production theory cannot be applied

The Abatement Cost Approach

- Adjusts the output of the plant to account for the shadow prices of pollutants

  [Pittman (1981, 1983), Fare et al. (1993), Coggins and Swinton (1996), Kumar (1999), Murty and Kumar (2000)];

- Accounts for the effect of pollution abatement costs on the total factor productivity

  [Gollop and Roberts (1983), Barbara and McConnell(1990), Jaffe et al. (1995), Jenkins (1998), Gray and Shadbegian (2002),Volkman (2003)]

- Studies use conventional production, cost, or profit functions

The Distance Function Approach

- Directly measures efficiency
- Computes the changes in inputs and outputs if pollution levels or abatement expenditures were not constrained.

  [Fare et al., (1986, 1989); Boyd and McClelland, (1999), Fare and Primont, (1995), Murty and Kumar (2003), Gupta (2005)]
- Mathematical programming techniques can be applied
- Existing applications use
  - non-parametric techniques or
  - parametric linear programming approach

Porter Hypothesis

- Strict regulations can lead to win-win opportunities
- Can stimulate firms to discover opprtunities
- Can enable firms to achieve cost effective compliance, thus increasing efficiency
- This can happen through stimulating technological innovation, and lesser input use through cleaner practices

Methodology

Three main methods to compute efficiency scores:

- Linear programming methods [*e.g., Fare et. al. (1993); Murty and Kumar (2002), Gupta (2005)*];
- Econometric methods [*e.g., Murty and Kumar (2003), Gray and Shadbegian (2003), and Kumar and Rao (2003), Kumbhakar et. al. (2007)*] and
- Data envelopment analysis, (DEA) [*e.g., Fare et. al., (1989), Fare and Grosskopf (2000)*];

Estimation

- We use the econometric method (using a stochastic frontier production function) to estimate the ODF and compute efficiency scores
- The econometric methodology that has been used is this paper follows Battese and Coelli(1992) and Coggins and Swinton (1996) in general, and the direction of Murty and Kumar (2003) in the Indian context
- The primary contribution of this paper is its data: plant level pollution and production data of **50** industrial units for **3 years** in and around Mumbai has been collected through a primary survey

Output Distance Function Approach

- Approach enables estimate shadow prices of pollution
- The absolute shadow price reflects the actual proportions of inputs used by an inefficient producer
- These prices reflect the trade-off between desirable and undesirable outputs at the “actual mix” of outputs
- These prices do not require that plants operate on the production frontier

Model Specifications

- Most common functional form used for analysis: the translog production function
- According to literature, assumptions of CES and Cobb-Douglas production functions are too restrictive for models with multiple outputs
- Especially restrictive when one output is an externality

Empirical Analysis

- Generalized production functions are estimated econometrically using the Stochastic Frontier Production Function Approach (SFA).
- Error term has two components:
  - for random effects and
  - for technical inefficiency
- Approach has been developed for using in panel data using maximum likelihood.
- Present model was estimated with translog production function

Empirical Analysis (Contd.)

- Stochastic output distance function for estimation is given as follows

$$D_0 = f(X,\ Y,\ \alpha,\ \beta)+\varepsilon$$

where D_0 is the distance measure, $f(.)$ is the production technology, X is a vector of inputs, Y is a vector of outputs, α, β are vectors of parameters to be estimated, and ε is the additive error term.

- Model for ODF and model for determinants of inefficiency simultaneously estimated

Study Area and Data Source

- Total reliable data was collected from 50 firms in industrial clusters in and around Mumbai
- Data of main plant --sales value (value of the good output), capital stock, wage bill, power and fuel cost and other material inputs
- Data of the effluent treatment plant -- wastewater volume, effluent quality for BOD (bio-oxygen demand), COD (chemical oxygen demand) and SS (suspended solids) {*the last three being the jointly produced bad outputs*}

Choice of Industry and Locations

- Chemical industry is one of the 17 categories of major polluting industries in India (categorized by CPCB)
- Suggested by Water Pollution Abatement Engineer of MPCB
- Study areas chosen from 17 industrial locations as suggested by MPCB
- They are Kalyan, Navi Mumbai, Raigarh and Thane

Descriptive Analysis of Pollution Data (Year-wise)

Table 1 : Violation of BOD norms

	Violated norms only in 1 year	*Violated norms in 2 years simultaneously*	*Violated norms in all 3 years*	*Did nor violate norms in any year*	*Total*
No. of firms	*12*	*6*	*8*	*24*	*50*

Table 2 : Violation of COD norms

	Violated norms only in 1 year	*Violated norms in 2 years simultaneously*	*Violated norms in all 3 years*	*Did nor violate norms in any year*	*Total*
No. of firms	*12*	*8*	*8*	*22*	*50*

Table 3 : Violation of SS norms

	Violated norms only in 1 year	*Vio lated norms in 2 years simultaneously*	*Violated norms in all 3 years*	*Did nor violate norms in any year*	*Total*
No. of firms	*9*	*6*	*6*	*29*	*50*

Descriptive Analysis of Pollution Data (All years)

Table 4: Pollution levels of observations

Pollution Combinations	Number of observations (150)
Not Polluting	93
Only BOD above mandatory level (not COD or SS)	1
Only COD above mandatory level (not BOD or SS)	4
Only SS above mandatory level (not BOD or COD)	3
Both BOD and COD above mandatory level (not SS)	13
Both COD and SS above mandatory level (not BOD)	2
Both BOD and SS above mandatory level (not COD)	1
All three pollutants above mandatory level	33

Comparison of Locations, year-wise

Table 5 : Pollution Matrix: Norms violated by number of firms from Navi Mumbai:

Year/ Parameter	BOD	COD	SS	All three pollutants
2004	2	2	2	2
2005	None	2	None	None
2006	2	1	None	None
All three years	None	None	None	None

Table 6 : Pollution Matrix: Norms violated by number of firms from Thane:

Year/ Parameter	BOD	COD	SS	All three pollutants
2004	2	4	3	2
2005	1	1	1	1
2006	3	3	2	2
All three years	1	1	1	1

Table 7 : Pollution Matrix: Norms violated by number of firms from Kalyan:

Year/ Parameter	*BOD*	*COD*	*SS*	*All three pollutants*
2004	*5*	*5*	*4*	*4*
2005	*9*	*9*	*5*	*5*
2006	*5*	*5*	*6*	*5*
All three years	*4*	*4*	*3*	*3*

Table 8: Pollution Matrix: Norms violated by number of firms from Raigarh:

Year/ Parameter	*BOD*	*COD*	*SS*	*All three pollutants*
2004	*6*	*6*	*6*	*5*
2005	*7*	*7*	*5*	*4*
2006	*6*	*7*	*5*	*3*
All three years	*3*	*3*	*2*	*2*

Descriptive Analysis of Pollution Data of 50 plants (Location wise) (contd.)

Table 9 : A location-wise comparison of the mean values of pollution parameters:

Pollution/Location	Norms	Navi Mumbai	Thane	Kalyan	Raigarh
BOD	*100 mg/l*	*77.97*	*119.32*	*210.48*	*135.37*
COD	*250 mg/l*	*217.27*	*305.13*	*483.7*	*481.14*
SS	*100 mg/l*	*64.71*	*85.06*	*117.48*	*85.68*
Number of firms		*6*	*6*	*10*	*28*

Kalyan: A Pollution hub?

- More heavily polluted than others
- MPCB field office extremely shabbily maintained
- No proper documentation of pollution data
- Field officers often not in office and no one knew or disclosed where they were!
- Field officer interviewed admitted of rampant corruption
- It has been alleged that polluting firms liase with corrupt MPCB officials to get a zero discharge certificate and get away from any penalty
- Such firms also dump the untreated toxins in nearest water body or sewage system

Results of Econometric Analysis

Table 1:Descriptive Statistics of the Data Used in the Study and Estimates of Technical Efficiency

Variable	*Mean*	*SD*	*Max*	*Min*
Efficiency	*0.452*	*0.135*	*0.913*	*0.203*
Turnover (Rs. crores)	*285.68*	*540.77*	*3102.09*	*0.93*
BOD concentration (mg/l)	*141.58*	*241.36*	*935*	*4*
COD concentration (mg/l)	*428.86*	*1003.60*	*3760*	*5*
SS concentration (mg/l)	*89.41*	*104.78*	*710*	*8.71*
Materials (Rs. crores)	*150.86*	*289.40*	*1645.61*	*0.26*
Wage Bill (Rs. crores)	*18.12*	*35.70*	*176.6*	*0.26*
Capital Stock (Rs. crores)	*167.52*	*304.74*	*1803.34*	*1.72*
Regulation Index (RI)	*0.075*	*0.119*	*1*	*0.0042*
Energy use /Sales (P)	*0.095*	*0.12*	*1.22*	*0.00045*

Results Contd.

Table 2:
Parameter Estimates of the Output Distance Function (Stochastic Estimation)

	Parameter	Coefficient	Standard-error	t-ratio	Significant
Constant	β_0	-1.764173	.5031843	-3.51	*at 1 percent*
Y_2	β_1	-.3716301	.2066487	-1.80	*at 5 percent*
Y_3	β_2	.5060281	.2038994	2.48	*at 1 percent*
Y_4	β_3	.3406323	.161126	2.11	*at 5 percent*
X_1	β_4	.530574	.1794441	2.96	*at 1 percent*
X_2	β_5	-.5874023	.2147927	-2.73	*at 1 percent*
X_3	β_6	-.3744248	.1638544	-2.29	*at 1 percent*
Y_2^2	β_7	.1284999	.1168427	1.10	*not significant*
Y_3^2	β_8	.2729714	.0857065	3.18	*at 1 percent*
Y_4^2	β_9	-.0491169	.0663983	-0.74	*at 1 percent*
X_1^2	β_{10}	-.2108427	.036833	-5.72	*at 1 percent*
X_2^2	β_{11}	.03817	.0632187	0.60	*not significant*
X_3^2	β_{12}	-.2008579	.0355166	-5.66	*at 1 percent*
Y_2Y_3	β_{13}	-.2157537	.097422	-2.21	*at 5 percent*
Y_2Y_4	β_{14}	.0624188	.0517177	1.21	*not significant*
Y_2X_1	β_{15}	.2950312	.0767292	3.85	*at 1 percent*
Y_2X_2	β_{16}	-.2562072	.0665592	-3.85	*at 1 percent*
Y_2X_3	β_{17}	-.1004355	.0690491	-1.45	*not significant*

Results Contd.

Table: 2 (contd.)

Parameter Estimates of the Output Distance Function (Stochastic Estimation)

Y_3Y_4	β_{18}	-.0611633	.055735	-1.10	*not significant*
Y_3X_1	β_{19}	-.3935885	.0772497	-5.10	*at 1 percent*
Y_3X_2	β_{20}	.2827009	.0746817	3.79	*at 1 percent*
Y_3X_3	β_{21}	.102039	.0638009	1.60	*not significant*
Y_4X_1	β_{22}	-.006905	.0361907	-0.19	*not significant*
Y_4X_2	β_{23}	.0406057	.0399619	1.02	*not significant*
Y_4X_3	β_{24}	-.10259	.0623698	-1.64	*at 10 percent*
X_1X_2	β_{25}	-.0356616	.040445	-0.88	*not significant*
X_1X_3	β_{26}	.0602613	.0250893	2.40	*at 1 percent*
X_2X_3	β_{27}	.0274707	.053536	0.51	*not significant*
μ		.8013691	.1960924	4.09	*at 1 percent*
Log-likelihood fn.		29.182			

Note: Y_2, Y_3 ,Y_4 are BOD/Turnover, COD/Turnover, SS/ Turnover respectively, while X_1, X_2, X_3 are Capital stock, Labour, and Materials respectively.

Results (continued)

Table 3:
Effect of Environmental Regulation on Technical Inefficiency

	Parameter	*Coefficient*	*Standard-error*	*t-ratio*	*Significant*
Constant	δ_0	0.101	.2374		
RI	δ_1	0.6885	.1328	5.19	*at 1 percent*
P	δ_2	0.3941	.1152	-3.42	*at 1 percent*
Time	δ_3	-0.0454	.0423	1.07	*not significant*
	γ	0.8219	.0408	3.18	*at 1 percent*

RI or Regulation Index ranges from 0 to 1
Firms with lower RI have lower levels of pollution; so we can say that they are more compliant to regulation.
P indicates Energy Efficiency; lower the value of P, more energy efficient the firm is.

Conclusion

- By estimating the ODF, we find almost all estimated values of the production function significant
- Within the survey area we find 55 percent firms are inefficient
- The indices that were used to determine the relationship between environmental regulation and technical efficiency were significant except for time
- We find that more the industry complies with the regulation or increases its effort on conservation (i.e. value of RI decreases), more efficient it becomes.
- We also find firms using energy in a more efficient manner are technically more efficient in general
- The signs of all three variables that explain technical efficiency were in accordance with the ‘win-win’ hypothesis.

Thank You