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Regulation, Efficiency and its Determinants: A Stochastic DEA Approach for Indian Cement Industry

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Abstract

The paper assesses the difference in the nature of relationship between efficiency and its determinants of Indian cement producing firms in the presence and absence of environmental regulation. It also shows how it changes with maturity in the regulatory process. An intuitive construct is followed by empirical verification using two-stage stochastic DEA (Banker and Natarajan 2007). The main findings suggest if all firms choose to comply, there exist potential for efficiency gains under regulation, the intensity of which decreases over time. Capital intensity of output plays a positive role in increasing efficiency under regulation in the initial phase, material intensity in both phases and labor intensity, a negative role, in the subsequent phase. Higher levels of abatement cause higher efficiency under regulation. While in the initial phase private firms report higher efficiencies under regulation, it is just the reverse in the subsequent phase. Size, age and development indicator of the state in which a firm is located play a positive role to achieve higher efficiencies in the matured phase of regulation.

Introduction

Differences in efficiencies of firms in an industry can be because of various reasons. This can be a consequence of using different technologies or different scales of operation. Even with similar technology and same scale of operation firms often achieve different output levels from the same level of inputs which implies there can be sources of inefficiency in the production process itself.

Several sources of this inefficiency can be described. A well-structured and widely accepted approach following Farrel (1957) splits this into allocative and technical inefficiency. Allocative inefficiency is defined as failure to choose the optimal combination of inputs at the given price ratio ie to say the inefficiency is caused due to higher-than-optimal total inputs used by a firm. Technical inefficiency is the failure to achieve maximum possible outputs from whatever levels of inputs are chosen.

Our study concentrates on the technical efficiency as this has been the most difficult component to quantify (Caves and Barton, 1990) and also an important source for explaining performance. From the literature it is evident that the differences in performance levels of firms can be largely due to inability to exploit factors of production because of poor managerial and operatives skills (Daly et al 1985, Greene and Mayes, 1991) rather than lack or shortage of factors of production. Technical efficiency embodies the managerial and organizational sources of efficiency, what Leibenstein (1966) refers to as X efficiency.

Identifying the determinants of technical efficiency of an industry is a challenging task. It consists of a set of factors directly related to technology choice and other production decisions of the firm which in turn depends on the stage of production in which the firm operates. Characteristics of firms like size, age, type of ownership, location, can influence efficiency too.

Imposition of a regulatory constraint can change certain decision parameters of the firm. There can be a change in the choice of technology to accommodate the effect of regulation, a shift in the firms' policy of R&D or skill formation, a diversion of managerial resources or a thorough shuffle and alteration in the basket of materials used for production. As a result the set of determinants of efficiency in the presence of regulation can be different than that in the absence of regulation. Also there is a difference in the nature of their relationship in the two scenarios. Also, under regulation, the nature of relationship might not be the same over time as the firms' strategies to comply with regulation in the initial phases may change in the subsequent phases of regulation depending upon the nature of its internal re-organisation.

The paper raises a few interesting questions relating to efficiency and its determinants in the Indian cement industry. First, it provides a simple intuitive framework to model efficiency by identifying a set of determinants. Second, it proposes the necessary modification in the framework to accommodate the imposition of environmental regulations in the industry. Third, it also analyses whether the nature of relationship between efficiency and its determinants differ between the initial and subsequent phases of regulation. The intuitive construct is followed by an empirical verification. A two stage stochastic Data Envelopment Analysis (DEA) methodology (Banker and Natarajan 2007) is used for the analysis which comprises of derivation of efficiency scores by DEA in the first stage and an econometric estimation explaining efficiency in the second stage.

The paper is organized as follows. Section 2 gives a snapshot of the literature to find a gap and justify the contribution of the present analysis; Section 3 elaborates on the data; section 4 on the methodology; Section 5 describes the results and the concluding remarks are given in Section 6.

2. Prior Work

The literature has failed to specify a structural model involving efficiency and its determinants[1]. However, there have been nationwide detailed empirical studies on determinants of efficiency on US (Caves 1988), UK (Green and Mayes 1991), Australia (Harris 1989), Portugal (Faria et al 2005)[2], India (Neogi and Ghosh 1994, Coondoo and Neogi, 1998), Spain (Doraszelskit and Jaumandreut 2007;Gumbau 2002) mainly for the manufacturing and industrial sector. Among the sector specific studies we can cite a few like those on dairy farms of US (Kumbhakar et al 1991) and

[1] Lovell (1993)
[2] studies the effect of technological flexibility on technical efficiency

Sweden (Forsund et al 1979), textile (Bhandari and Maiti 2006), engineering (Goldar et al 2004), washing soap (Goldar1985), thermal power plants (Singh 1991) and small scale industries (Goldar1988, Bhawani1991, Ramaswamy 1994) in India.

A single or a double step methodology is followed for empirical estimations; either with parametric or non parametric classification, with deterministic or econometric formulations. Determinants identified are diverse, comprising mostly of categorical variables like size, age, type of ownership or location, or quantitative variables like efforts on R&D, and other inputs or degree of competition in the market. However, no unique answer relating the characteristics of firms like size, type of ownership or age with their efficiency have been offered. (Bhandari and Maiti 2006, Singh 1991) An intuitive framework behind the estimations is missing. Though it is well accepted that factor shares or factor productivities can influence efficiency, relationships of these kinds have never been explored empirically.

Also, there has been no attempt to study how the nature of determinants of efficiency can change in the presence of regulation[3].

The literature relating regulation and efficiency in general is diverse and scattered. The main issue addressed has been whether imposition of regulation leads to a fall in efficiency in the industry. While regulation constraining the rate of return of a monopoly firm is bound to reduce its overall efficiency theoretically (Averech and Johnson,1962), conclusions based on empirical evidence on the effect of regulation on technical efficiencies of firms is somewhat ambiguous (Sickles and Streitweiser 1991, Barla and Perelman 1989, Fecher and Pestieau 1993). 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 (Shapiro and Willig 1990, Pint 1991, Laffont and Tirole 1990).

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 has been evidence in favor of Porter hypothesis (Boyd and McClelland 1999, Murty and Kumar 2003, Murty et al 2007) for different industries and for various pollutants in US and India. Bandyopadhyay (2005) estimates the technical efficiencies of seventeen highly polluting industries in India under environmental regulations, which attempts to relate the efficiency levels to location, type of ownership and size of firms. However, the

[3] However we find some studies touching upon the issue of an influence of a reform in an economy on TEs, a few among them being Movshuk (2004) and Ray and Ping (2006) for the impact State Owned Enterprises reforms in China respectively on TEs of Iron and Steel and the manufacturing industries, Fan (1999) analyzing the impact of rural reforms based on decentralization on TEs of Chinese agriculture farms; Cotfas et al (2000) on the effect of reforms on TEs of Romanian Cement Industry, Neogi and Ghosh (1994) on the effect of liberalization policies on TEs of Indian manufacturing industries.

nature of relationships differs across industries. Recently Banerjee (2007) addresses the issue of whether environmental regulation in India has the potential to induce higher efficiency levels for industries and finds some positive answers.

A close look at the empirical literature on efficiencies in the presence of environmental regulations on Indian industries reveals that all of them (Kumar et al 2007, Bandyopadhyay 2005, Murty and Kumar 2002) concentrates on deriving the technical efficiency scores in the presence of environmental regulations and then offering some policy conclusions on the basis of that. A detailed model identifying the determinants of TE of such industries and how it differs in the presence of environmental regulation is not explored. Bandyopadhyay (2005) however attempts to relate the TEs with the internal characteristics like size and type of ownership but whether the nature of relationship is different in the presence and absence of environmental regulation is not analysed. Banerjee (2007) and Bandyopadhyay (2008) have derived the efficiency scores in the presence and absence of regulation and compared them but how in each scenario efficiency can be explained by a set of factors and what explains the differences in efficiencies across firms with and without regulation and those under regulation across its different phases, is not explored.

Continuing on the line of Bandyopadhyay (2008) this paper investigates further into the possible sources of inefficiency in two different scenarios, one in which all firms comply with regulation by investing additional resources in pollution control mechanisms and the other in which the firms do not face any regulation. The analysis develops a simple intuitive framework relating efficiency to a set of determinants including factor intensities of output, groaa value added, pollution abated and some categorical variables, in the presence and absence of regulation. It also provides an empirical verification of the theoretical construct for each of the scenarios using a two stage stochastic DEA model.

3. Data and Variables

We have used establishment level data for 1999-00 and 2003-04 published by Annual Survey of Industries (ASI), Central Statistical Organisation (CSO), 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.

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[4].

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 A1 in the Appendix gives the heading of each block.

[4] 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.

For DEA in stage 1, we have used extensively Blocks A, C, D, E, H, and J. From Block A the first round of screening gives the list of firms which are in operation.

Block C gives the values of net fixed assets (FCAPM) for each unit (expressed in Rs) which 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.

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

From Block H the figures for consumption of inputs are extracted. Among the basic inputs ASI records 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. 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.

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). Ten major products and by-products manufactured by a firm with their production and sales figures, item and unit codes, are reported.

The pollution figures are generated from the emission coefficients given by Central Pollution Control Board for Particulate Matter emission in cement industry. Two sets of coefficients are given on the basis of standard production practices in India with and without control devices. The list of variables used to derive efficiency scores by DEA and their descriptive statistics are given in Table A 2 and A 3 in the Appendix.

For Stage 2 of the analysis which involves econometric estimations we have used all the blocks excepting I for imported inputs for which there is hardly any data for Cement.

Total output is defined as the sum of ex-factory value of output from Block J and other incomes from Block G. Total input is defined as the sum of materials consumed, fuels used from Block H and other expenses from Block F). Gross value added is defined as the difference between total output and total inputs.

We take the ratios of capital to output, materials to output, and labor to output as three explanatory variables for regression in the second stage. The amount of pollution abated by adopting control devices is also taken as one of the explanatory variables in the scenario with environmental regulation.

The entire range of FCAPM from Block C, separately for 99-00 and 03-04, is divided into quartiles, the first quartile is considered as small, the two middle quartiles as medium and the last quartile as large[5]. These quartiles are used to construct the dummies on size.

Block B gives the age and type of ownership of the firms. Age is calculated as the difference between the initial year of operation and the year of publication of the data. The first quartile of the

[5] Investment limits in plant and machinery as the criteria determining the size as specified by the industrial authorities in India have changed over the period of our study. For comparability purposes we have used the quartiles to determine the size in each year.

age distribution in each year is taken to construct the dummy on young, the middle two quartiles for middle and the last quartile for old age of the firm. We have six ownership 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). We club the firms belonging to codes 1 to 5 as non-private and take code 6 as private. The ownership category dummy, downr, is constructed to see the difference in efficiency between private and non private firms.

Block A gives the state specific locations of the firms and also gives the codes for rural or urban areas. The dummy variable dstate, is constructed on the basis of some development indicators of the states and makes a comparison between the backward states with the developed ones; dru captures the difference between firms located in rural or urban areas. The variables with description are listed in Table A 4 in the Appendix.

4. Methodology

Banker et al (2007) has established a two stage methodology as a non parametric counterpart of stochastic frontier production approach. The analysis shows that the estimates generated by a two stage method comprising of DEA in the first stage and an OLS or Tobit in the second stage can satisfy some desirable statistical properties not ensured by the non parametric DEA approach. The model is developed in a framework where the set of input variables used in stage 1 and contextual variables in stage 2 are independent. It is also shown that the model works well, with a slight loss in the degree of robustness, in the presence of low negative correlation and reasonably high positive correlations between the two sets of variables mentioned above. It is also established that DEA followed by OLS outperforms all the one stage as well as two stage procedures. We check for these conditions and carry out the analysis.

Stage 1

The first step in our analysis is based on BCC (1984) framework for deriving the efficiency scores in the scenario where regulation is absent. The same model is modified to incorporate weak disposability of bad outputs in the scenario where regulation is present. We solve two models for each point of time to generate two sets of efficiency scores at each point of time. This draws on Bandyopadhyay (2008).

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 $x^/ = \lambda x^0 + (1-\lambda) x^1$, $y^/ = \lambda y^0 + (1-\lambda) y^1$, $0 \leq \lambda \leq 1$.

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

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 $T^v=\{(x,y) : x\geq \Sigma\lambda_j x^j ;\ y\leq \Sigma\lambda_j y^j ;\ \Sigma\lambda_j =1;\ \lambda_j\geq 0, j=1(1)n\}$, the smallest of all the sets satisfying assumptions (i) - (iv).is 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 virtual prices that maximizes AP_j

sub to $AP_j \leq 1$ (j=1,….,t,…N)

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

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

Let $(\Theta^*, \mu^*_{1,.........,} \mu^*_N)$ 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**:

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

We would use the 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 Φ^*.The efficiency scores generated in Model 1 can be termed as 'eff's.

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:

$T^{v}_{w}=\{x,y) : x\geq \Sigma\lambda_j x^j ;\ y = \alpha\, \Sigma\lambda_j y^j ;\ \Sigma\lambda_j =1;\ \ \lambda_j\geq 0,\ 0 \leq \alpha \leq 1;\ j=1(1)n\}$.[6]

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 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. This implies that firms invest additional resources for compliance with environmental regulation. Mathematically, by incorporating the bad output constraint as equality in an LPP we are actually allowing our model to have non-positive shadow prices for the bad outputs, which is compatible with an economic model of pollution control. The efficiency scores generated in Model 2 can be termed as 'effw's.

Stage 2

In this part we would attempt to identify some important determinants of technical efficiency in two scenarios elaborated in Models 1 and 2 of Stage 1. The main objective would be to define a meaningful relationship between the technical efficiency scores in each scenario and their respective determinants through a simple intuitive construct and then verify

[6] 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).

the same empirically from the available data. The focal point of the analysis centers around the differences in the nature of these relationships brought about by the imposition of regulation, and in the presence of regulation whether the nature of relationship differs between its initial and subsequent phases.

The section is divided into two parts: The first part elaborates on the intuitive framework in which the determinants of technical efficiency are identified. The second section illustrates the econometric estimation procedure involved in estimating the relationship of efficiency and its determinants in the two scenarios.

Identifying the Determinants: An Intuitive Construct

We intend to identify a set of variables which affect the technical efficiency scores of the firms in the presence and absence of environmental regulations. The set of explanatory variables directly related to the production process, like the input-output ratios, gross value added, pollution abated (where we consider environmental regulation to be present), etc. of the firms are identified using the principle following which the DEA scores are derived, the basic principle of production theory in economics and the characteristics of standard abatement technology used in Cement industry. A set of categorical variables related to the characteristics of the firms like size, age and location parameters, are also included.

The output efficiency score of a firm using DEA is derived from maximized ratios of total potential earning from production of a firm to its total expenditure on inputs, with non negative virtual prices assumed in course of the optimization exercise. This score is an index of productivity of a firm relative to a hypothetical firm producing the maximum possible output from the same input quantities used by the observed firm. It would be interesting to know how this index of total factor productivity is related to individual factor productivities.

We relate the scores generated to individual factor intensities of output. It is clear that the basic intuition behind deriving these scores can be interpreted as 'lesser the input-output ratio, higher the efficiency scores'. But if we want to estimate empirically the relation between individual factor productivities and efficiency, it would depend on the stage of production in which the firm operates. If a rise in the share of a factor can cause an increase in the level of production, it can push the firm closer to the frontier which in turn increases efficiency. Whether a rise in factor share would have a positive impact on efficiency would depend on the stage of production in which the firm operates. So in our model the signs of the factor intensities as determinants of efficiency are a matter of empirical investigation.

The principle followed in deriving efficiency scores in the case of weak disposability of bad outputs (incorporating effective environmental regulation) has an additional dimension. These scores reflect the capability of the firms to produce less of the bad output. Thus the relationship between input-output ratios (expressed in terms of the good output) and these scores depend on the relative strength of the two sets of effects acting in opposite directions.

One component of 'effw's generated in Model 2 in Stage 1 of the paper, which is determined by the expansion of good output is expected to behave in the same way with variation in input-output ratios as do 'eff 's in Model 1. The behavior of the other component (which is determined by the reduction in bad output) would depend on the nature of abatement technology used and the stage of operation of this technology for a firm. So the determinants of 'effw's would be a combination of factors affecting technology of production of a firm and its adopted abatement technology for reducing pollution.

Abatement technology most commonly used for PM abatement in cement industry is Electro Static Precipitator which generally requires higher expenditure on capital in the initial stage followed by operation and maintenance costs in latter stages mostly in terms of higher expenditures on energy consumption and use of better substitute inputs like lower ash fuels[7]. Thus, intuitively we can suggest that in the initial phases of adoption of abatement technology a higher 'effw' can be an outcome of a higher capital to output and a higher material to output ratio whereas that in the latter stages is more likely to be associated with higher material to output ratio. The role of labour to output ratio remains somewhat ambiguous in all the stages as is that of the capital to output ratio in the latter stages of adoption of abatement technology, depending upon the stage of production in which a firm operates.

To make our model more complete, we have identified gross value added of a firm as another determinant explaining efficiency in both the scenarios. In both the scenarios, a higher efficiency score is likely to be associated with a higher gross value added.

For effw, we would also add the 'amount of pollution abated' defined as the difference in pollution emissions before and after the abatement technology is being adopted. A higher abatement level is likely to cause a higher effw.

The relationship between technical efficiency scores with the categorical variables like size, age, location and type of ownership of the firms are often ambiguous. There cannot be any consensus regarding the effect of these variables on efficiency as is evident from the literature reviewed in the preceding section as these effects would be specific to industries and the market structure in which they operate. So they are only subject to empirical investigation.

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[7] 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 of international standards reveals that they aim at fulfilling multiple objectives of material recovery and recycling with pollution abatement (http://www.cibo.org; http://www.ifc.org).

Empirical Estimation

To provide an empirical verification of our intuitive construct in the second stage we estimate three models separately for each of the scenarios (altogether six models) according to the intuitive construct developed for each. Scenario 1 corresponds to the efficiency scores generated in Model 1 of stage 1 whereas Scenario 2 corresponds to Model 2. All the six models are run using OLS and Tobit regressions. Effs and effws generated in stage I of the paper are regressed separately on the set of explanatory variables identified in the previous section and elaborated in Section 2, for 99-00 and 03-04 separately[8]. A standard log-log model is estimated for each category and also for each year. We have done three sets of regressions for each year for each scenario[9]. We have orthgonalised each set of variables for the respective models and used them as regressors so that each regressor captures its own effect singled out from the others wherever they are related. The reduced form equations can be written as follows:

Model 1: $leff_i^{\,j}$ = F ($lgva_i^{\,j}$, $lcapout_i^{\,j}$, $latout_i^{\,j}$, $llabout_i^{\,j}$, dstate, dru, dyoung, dmiddle, dsmall, dmedium, downr)

Model 2 : $leff_i^{\,j}$ = f ($lgva_i^{\,j}$, $lcapout_i^{\,j}$, $latout_i^{\,j}$, $llabout_i^{\,j}$)

Model 3: $eff_i^{\,j}$ = fd (dstate, dru, dyoung, dmiddle, dsmall, dmedium, downr)

Model 4: $leffw_i^{\,j}$ = G ($lpoll_i^{\,j}$, $lgva_i^{\,j}$, $lcapout_i^{\,j}$, $lmatout_i^{\,j}$, $llabout_i^{\,j}$, dstate, dru, dyoung, dmiddle, dsmall, dmedium, downr);

Model 5: $leffw_i^{\,j}$ = g ($lpoll_i^{\,j}$, $lgva_i^{\,j}$, $lcapout_i^{\,j}$, $lmatout_i^{\,j}$, $llabout_i$);

Model 6: $effw_i^{\,j}$ = gd (dstate, dru, dyoung, dmiddle, dsmall, dmedium, downr)

j=index for year

i=index for a firm

[8] There are problems constructing even an unbalanced panel from ASI data used in our analysis. CSO changes the frame for stratified sampling every year and the firm identification codes are not disclosed.

[9] For Details see Table 2

5 Results

Table 1 below summarises the results of the two models in each of the two time periods for stage 1 of the analysis. We find that for both the time periods, the efficiency scores of firms in the weak disposability model are either higher or equal to those in the free disposability model. In 1999-00 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 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, in the average level of productive efficiency for cement industry can go up by **8 percentage points** if cement firms are willing to take initiatives to comply with the environmental standard. This translates, on an average in relative terms, to an increase by **12%**.

For 2003-04, 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 in this case also. 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 at least **2 percentage points** if cement firms are ready to comply with the environmental standard. This translates, on an average in relative terms, to an increase by **3%**.

Table 1: Descriptive Statistics of the DEA Efficiency Scores

	Efficiency Scores Weak Disposability (Model 2)		Efficiency Scores Free Disposability (Model 1)	
Year	99-00	03-04	99-00	03-04
N	68	243	68	243
Mean	0.76	0.65	0.68	0.63
Median	0.81	0.64	0.73	0.61
Std. Deviation	0.30	0.27	0.29	0.26

In stage 2 the efficiency scores are regressed on a set of explanatory variables identified in the previous section. Tables A 5-A 12 in the Appendix elaborate the results of a set of OLS Regressions. Table 2 below summarises the main findings.

Six[10] models are estimated for our purpose separately for two years, using both OLS and Tobit. We compare in pairs, Model 1 and Model 4, Model 2 and Model 5, Model 3 and Model 6 to scruitinise the effect of imposition of an environmental regulation on efficiency captured through different sets of variables. For each model comparison across time would give an idea about a change in the causal relationship with time.

Comparing Model 1 and Model 4 for 1999-00 we notice that there is a reversal of sign of lcapout from negative to positive which implies that in the absence of regulation the firms

[10] The regressors are chosen in three groups, combining quantitative and qualitative variables (Models 1 and 4), only quantitative variables (Models 2 and 5) and only qualitative variables (Models 3 and 6) comparisons of models 2 and 5 are not explained separately as the results of models 1 and 4 and models 4 and 5 for the quantitative variables are the same.

with higher capital intensity in output would have lower efficiencies whereas with the imposition of regulation firms with higher capital intensity of output record higher levels of efficiencies. Material-output ratio is insignificant in the scenario where there is no regulation whereas it is positive and significant in the scenario with environmental compliance. There is no change in the sign of llabout[11], it remains negative and significant for both the models implying that by increasing the labor intensity of output, irrespective of the presence or absence of regulation, firms are not likely to gain in terms of efficiency. Firms with higher levels of abatement record higher efficiency in Model 4. The higher efficiency levels recorded by the private firms in Model 1 can no longer be retained when environmental regulations are imposed.

For 2003-04, material to output ratio which is insignificant in scenario 1 becomes positive and significant in scenario 2 which means firms with higher material to output ratios are associated with higher levels of efficiencies in the presence of environmental regulations; llabout which is not significant in Model 1 becomes significant and negative in Model 4 which implies that in the presence of regulation firms with lower labour-output ratios are associated with higher efficiencies whereas in the scenario where regulation is absent, differences in labour-output ratios cannot explain differences in efficiencies. The signs of lcapout which is negative, lgva which is positive, remain the same in both the scenarios. Among the categorical variables, dstate is positive for both the models indicating that firms located in states with higher development indicators report higher efficiencies in the presence as well as absence of regulation. The medium and small sized firms are reported to achieve lower efficiencies than the large firms indicating that size has an advantage to achieve higher efficiencies in both the scenarios.

[11] The description refers to the OLS regressions results as DEA followed by OLS outperforms many parametric methodologies. Apart from Model 1 for the year 2003-04, there is no difference in the results for OLS and TOBIT in the second stage. The difference in Model 1 does not alter the basic conclusions however.

Comparing Model 3 and Model 6 for 1999-00 we find private firms have higher efficiencies in both the models than non-private firms. Larger firms have higher efficiencies than small firms in the absence of regulation, which is no longer valid with the imposition of regulation. For 2003-04, the comparison reveals that apart from the one dummy for age, there has been no change in the list of variables proved to be significant in explaining efficiencies with their respective signs across the Models in two scenarios. Firms located in the developed states have higher efficiency levels than those located in the less developed states; size of the firms are directly related to efficiency as reflected in the differences in efficiency levels between small, medium and large firms; non-private firms report higher efficiencies in both the models. Age as experience can play a positive role in the absence of regulation whereas in the presence of regulation, when compared between young and old firms the difference is significant whereas it is insignificant between middle and old categories.

Comparing Model 4 across the two time periods we get an idea about the behavior of the determinants of efficiency under regulation with maturity in the regulatory process. We find that between 99-00 and 2003-04 there is a reversal of sign in the coefficient for lcapout from positive to negative implying that increasing the capital intensity can lead to higher efficiency in the initial phase of regulation but in the latter phase, a higher capital intensity of output would result in lower efficiency. In the initial phase higher gross value added does not contribute to higher efficiency but in the latter lgva is positive and significant. Higher abatement levels and higher material intensity of output contribute to higher efficiencies in both the phases under regulation but the marginal impact of each of the variable being higher in the initial phase. This is true with labor intensity of output also which has a negative impact on efficiency in both the phases. In the initial phases size does not play a positive role

Table 2: Results for Alternative Models in Stage 2: Summary

Scenarios	Model	Dependent Variable	Independent Variables	Significant Variables (OLS)				Significant Variables (TOBIT)			
				99-00		03-04		99-00		03-04	
				Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Scenario 1: No regulation	Model 1	Leff	lgva, lcapout, lmatout, llabout, dstate, dru, dyoung, dmiddle, dsmall, dmedium, downr	downr	lcapout llabout	lgva dstate	capout, dsmall, dmedium	downr	lcapout llabout,	lgva dstate	llabout,
	Model 2	Leff	lgva, lcapout, lmatout, llabout		lcapout llabout	lgva	lcapout		lcapout llabout	lgva	llabout,
	Model 3	Eff	dstate, dru, dyoung, dmiddle, dsmall, dmedium, downr	downr	dsmall	dstate	dyoung dmiddle dsmall dmedium downr	downr	dsmall	dstate	dyoung dmiddle dsmall dmedium downr
Scenario 2: Regulation	Model 4	Leffw	lpoll, lgva, lcapout, lmatout, llabout, dstate, dru, dyoung, dmiddle, dsmall, dmedium, downr	lcapout, lmatout, lpoll	llabout	lgva lpoll, lmatout, dstate	lcapout llabout dsmall dmedium	lcapout, lmatout, lpoll	llabout	lgva lpoll, lmatout dstate	lcapout
	Model 5	Leffw	lpoll, lgva, lcapout, lmatout, llabout	lcapout, lmatout, lpoll	llabout	lgva lpoll, lmatout	lcapout, llabout	lcapout lmatout lpoll	llabout	lgva lpoll, lmatout	lcapout
	Model 6	Effw	dstate, dru, dyoung, dmiddle, dsmall, dmedium, downr	downr		dstate	dsmall dmedium downr dyoung	downr		dstate	dsmall dmedium downr dyoung

in achieving higher efficiency under regulation but in the latter phase large firms report higher efficiencies compared to those of the small and medium firms.

6. Conclusions

The present analysis deals with the effect of environmental regulations on cement producing firms in India. We use a two stage stochastic DEA model proposed by Banker and Natarajan (2007). Our first task is to identify a set of input variables to be used to generate DEA scores of efficiency in the first stage which has a reasonably low correlation with a set of variables used to explain the sources of inefficiency in the second stage, guided by an intuitive construct. Stage 1 derives the efficiency scores in two scenarios, one in which environment regulation is present and the other in which it is absent. It is found that the firms can gain in terms of efficiency levels by complying with environmental regulations. The analysis is done for two time periods, one in the initial years of implementation of environmental regulations in 99-00 and a subsequent phase in 2003-04.

The magnitude of gains is found to be relatively higher in the initial phase. The main findings suggest 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 in turn enables the firms to achieve higher productive efficiency.

The second part of the analysis deals with modeling the sources of (in) efficiency in the two scenarios mentioned above and pinpoint the differences in the nature of the relationship between the scenarios. We find that in the initial phases of regulation capital intensity can play an important role in contributing to higher efficiency of the firms under regulation. Material intensity of output plays a positive role in both the phases of regulation. This is in line with the nature of standard abatement technologies adopted in the cement industry for PM abatement which requires higher capital investments initially followed by higher expenditures on improved raw materials with lower potential for emissions. Also, it is found that higher capital intensity can play a positive role in increasing efficiency in the presence of regulation which is just the reverse in the absence of regulation in the initial phase. Labor intensity of output cannot play a positive role in explaining efficiency in any of the phases considered. This implies that there is a scope for increasing efficiency through substitution of expenses on labor by those on capital and/or material in the initial phase. With maturity in the regulatory process, the substitution of expenses on labor and/or capital by that of material can lead to a gain in efficiency.

A close look at the effect of categorical variables on efficiency reveals that the firms' location in rural or urban areas does not explain much in any of the scenarios. Private firms in 99-00 record higher efficiencies in the scenario without regulation but in the presence of regulations this difference is not significant. In the subsequent phases of regulation the private firms report relatively lower efficiencies. This indicates that the non private enterprises utilize their resources better for environmental control than their private counterparts. Size, age and development indicators of states in which firms are located play a positive role in achieving higher efficiency levels under environmental regulations.

The analysis is subject to some limitations. Due to non availability of panel data, it is restricted to a two period analysis. Because of this the conclusions might be subject to some bias due to sample selection. Second, Banker and Natarajan (2007) framework performs better in situations where there is positive correlations between the input variables in stage 1 and the contextual variables in stage 2 with slight decrease in the extent of robustness of the model. However, in our analysis we do encounter a small number of paired correlation coefficients between the input variables in stage 1 and the contextual variables in stage 2 which are high and negative. The problem is relatively more pronounced for the year 1999-00 but since the number of variables in the regression which are significant and has shown negative correlation is minimal, the problem can be ignored (Tables A 13-A 16). Orthogonalisation of the explanatory variables partially takes care of restoring the consistency properties from the other side.

In spite of these weaknesses the analysis is successful in telling a convincing story of how regulation can affect efficiency, how the determinants of efficiency behave in the presence and absence of regulation and how with maturity in the regulatory process the nature of relationship between efficiency and its determinants undergoes a change.

Appendix

Table A1 Block Descriptions: ASI Data

Block	Description
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

Table A 2 List of Variables used in DEA Models (Stage 1)

Variables		**Descriptions (Units)**
Output	EXFAC	Ex-factory value of all the products and bi-products produced by a cement firm (Rs)
	PM	Particulate Matter emissions without the use of control technologies (tonnes)
	PMA	Particulate Matter emissions with the use of control technologies (tonnes)
	MAT	Purchase value of all basic and non-basic inputs used for production (Rs)
Input	LAB	Total mandays generated
	FCAPM	Net value of fixed assets (Rs)
	WCAPM	Net value of current assets (Rs)

Table A 3: Descriptive Statistics of Variables Used in the DEA Models (Stage 1)

	MAT	LAB	FCAPM	WCAPM	EXFAC	PM	PMA
Year				**1999-2000**			
N	69	68	68	68	68	68	68
Mean	654,595,320	226,788	12,720,591,284	225,470,962	31,850,105,383	255,655	857
Median	542,106,170	214,977	5,213,137,460	106,414,000	793,598,353	170,523	572
SD	622,452,321	179,630	17,476,965,541	291,142,991	254,258,489,585	272,162	912
Minimum	935710	1,179	63059	246075	429,352	85	0.29
Maximum	2,177,960,187	865,452	77,315,616,165	1,624,460,000	2,097,670,127,000	980,841	3,288
Year				**2003-04**			
N	243	243	243	243	243	243	243
Mean	358,427,553	84,106	628,622,312	32,004,600	557,993,472	365,798	1,226
Median	20,718,936	12,550	13,713,300	1,271,100	23,902,576	4,371	15
SD	685,929,111	125,988	1,524,775,868	210,056,860	1,046,768,681	3,629,114	12,165
Minimum	72,820	411	7	-809,128,008	19,362	0.72	0.0024
Maximum	4,444,844,494	593,493	12,485,500,000	2,029,313,375	6,265,655,950	56,544,310	189,534

Table A 4 List of Variables used in Regressions (Stage 2)

Variables		Description
Quantitative	gva	gross value added of a firm
	poll	level of abatement of Particulate Matter of a firm
	capout	ratio of value of capital to value of output
	matout	ratio of value of materials consumed to value of output
	labout	ratio of expenditure on labour to value of output
Qualitative	dstate	dummy for state specific location of the firm
	dru	dummy for rural-urban location parameters of the firm
	downr	dummy for type of ownership of the firm
	dsmall	dummy for size of the firm
	dmedium	dummy for size of the firm
	dyoung	dummy for age of the firm
	dmiddle	dummy for age of the firm

Table A5 Regression Results in Stage 2 (Model 1):99-00

Source	SS	df	MS
Model	20.567978	11	1.86981618
Residual	30.2323842	47	.643242216
Total	50.8003622	58	.875868313

Number of obs	= 59
F(11, 47)	= 2.91
Prob > F	= 0.0053
R-squared	= 0.4049
Adj R-squared	= 0.2656
Root MSE	= .80202

leff	Coef.	t	P>|t|	[95% Conf.	Interval]
lmatout	.1800753	1.72	0.091	-.0299797	.3901304
lcapout	-.2836066	-2.72	0.009	-.4936617	-.0735515
llabout	-.3443037	-3.30	0.002	-.5543588	-.1342486
lgva	.0806837	0.77	0.444	-.1293714	.2907388
dstate	-.031796	-0.30	0.762	-.2418511	.1782591
dsmall	.0158057	0.15	0.880	-.1942494	.2258608
dmedium	-.0241995	-0.23	0.818	-.2342546	.1858556
dyoung	.0431594	0.41	0.681	-.1668957	.2532145
dmiddle	-.0648097	-0.62	0.538	-.2748648	.1452453
dru	.057347	0.55	0.585	-.1527081	.2674021
downr	.3154313	3.02	0.004	.1053762	.5254864
_cons	-.6684746	-6.40	0.000	-.8785297	-.4584195

Table A 6 Regression Results in Stage 2 (Model 1):03-04

Source	SS	df	MS
Model	33.4441831	11	3.04038028
Residual	77.2071886	178	.43374825
Total	110.651372	189	.585456993

Number of obs	=	190
F(11, 178)	=	7.01
Prob > F	=	0.0000
R-squared	=	0.3022
Adj R-squared	=	0.2591
Root MSE	=	.6586

lneff	Coef.	t	P>|t|	[95% Conf.	Interval]
dstate	.146689	3.07	0.002	.0524017	.2409762
dsmall	-.2504882	-5.24	0.000	-.3447755	-.156201
dmedium	-.1161459	-2.43	0.016	-.2104332	-.0218587
dyoung	.017767	0.37	0.710	-.0765203	.1120542
dmiddle	-.0541042	-1.13	0.259	-.1483915	.040183
dru	-.0019142	-0.04	0.968	-.0962014	.0923731
downr	-.0447459	-0.94	0.350	-.1390331	.0495414
lcapout	-.1780671	-3.73	0.000	-.2723544	-.0837799
lmatout	.0679287	1.42	0.157	-.0263586	.1622159
llabout	-.0647343	-1.35	0.177	-.1590215	.029553
lgva	.1803015	3.77	0.000	.0860142	.2745887
cons	-.5986842	-12.53	0.000	-.6929715	-.504397

Table A 7 Regression Results in Stage 2 (Model 3):99-00

Source	SS	df	MS
Model	1.59499571	7	.227856531
Residual	3.61502367	54	.066944883
Total	5.21001939	61	.085410154

Number of obs	=	62
F(7, 54)	=	3.40
Prob > F	=	0.0044
R-squared	=	0.3061
Adj R-squared	=	0.2162
Root MSE	=	.25874

eff	Coef.	t	P>|t|	[95% Conf.	Interval]
dstate	.0909113	1.32	0.192	-.0471269	.2289495
dyoung	-.0679763	-0.62	0.538	-.287804	.1518514
dmiddle	-.0237489	-0.27	0.785	-.1973579	.1498602
dsmall	-.2704931	-2.70	0.009	-.4713273	-.069659
dmedium	-.0612508	-0.72	0.475	-.2319914	.1094898
downr	.2969402	3.43	0.001	.123447	.4704334
dru	.0026963	0.03	0.976	-.179021	.1844136
cons	.471242	3.51	0.001	.2024379	.7400462

Table A 8 Regression Results in Stage 2 (Model 3) 03-04

Source	SS	df	MS
Model	3.02874729	7	.432678184
Residual	12.7239569	229	.055563131
Total	15.7527042	236	.066748747

Number of obs	=	237
F(7, 229)	=	7.79
Prob > F	=	0.0000
R-squared	=	0.1923
Adj R-squared	=	0.1676
Root MSE	=	.23572

eff	Coef.	t	P>|t|	[95% Conf.	Interval]
dstate	.0973123	2.95	0.003	.0323738	.1622508
dyoung	-.1203275	-2.57	0.011	-.2124521	-.0282029
dmiddle	-.0797019	-2.03	0.044	-.1571023	-.0023014
dsmall	-.1852605	-4.09	0.000	-.2744775	-.0960435
dmedium	-.129623	-3.36	0.001	-.2056811	-.0535648
downr	-.1584725	-2.38	0.018	-.2899101	-.027035
dru	.0294148	0.81	0.416	-.0417194	.100549
_cons	.871008	11.08	0.000	.7161156	1.0259

Table A 9 Regression Results in Stage 2 (Model 4): 99-00

Source	SS	df	MS
Model	35.2253471	12	2.93544559
Residual	15.7859168	46	.343172105
Total	51.0112639	58	.87950455

Number of obs	=	59
F(12, 46)	=	8.55
Prob > F	=	0.0000
R-squared	=	0.6905
Adj R-squared	=	0.6098
Root MSE	=	.58581

leffw	Coef.	t	P>|t|	[95% Conf.	Interval]
lgva	.0296653	0.39	0.699	-.1238499	.1831804
lcapout	.1660922	2.18	0.035	.012577	.3196073
lmatout	.3957453	5.19	0.000	.2422301	.5492604
llabout	-.2377026	-3.12	0.003	-.3912178	-.0841875
lpoll	.5826392	7.64	0.000	.429124	.7361543
dstate	.0468977	0.61	0.542	-.1066175	.2004128
dsmall	.0141261	0.19	0.854	-.139389	.1676412
dmedium	.0122216	0.16	0.873	-.1412936	.1657367
dyoung	.0880192	1.15	0.254	-.0654959	.2415344
dmiddle	-.066977	-0.88	0.384	-.2204921	.0865382
dru	.0342792	0.45	0.655	-.1192359	.1877944
downr	-.0055853	-0.07	0.942	-.1591004	.1479298
_cons	-.6145763	-8.06	0.000	-.7680914	-.4610611

Table A 10 Regression Results in Stage 2 (Model 4): 03-04

Source	SS	df	MS
Model	34.0917898	12	2.84098248
Residual	79.5089351	177	.449203023
Total	113.600725	189	.601062036

Number of obs	190
F(12, 177)	6.32
Prob > F	0.0000
R-squared	0.3001
Adj R-squared	0.2527
Root MSE	.67023

lneffw	Coef.	t	P>|t|	[95% Conf.	Interval]
dstate	.1535182	3.16	0.002	.0575622	.2494743
dsmall	-.2519563	-5.18	0.000	-.3479123	-.1560003
dmedium	-.1174774	-2.42	0.017	-.2134334	-.0215214
dyoung	.0200004	0.41	0.681	-.0759557	.1159564
dmiddle	-.0538741	-1.11	0.269	-.1498301	.0420819
dru	-.0111739	-0.23	0.819	-.1071299	.0847821
downr	-.051302	-1.06	0.293	-.147258	.044654
llabout	-.131653	-2.71	0.007	-.227609	-.035697
lpoll	.1188032	2.44	0.016	.0228472	.2147593
lgva	.1157612	2.38	0.018	.0198052	.2117172
lmatout	.1151632	2.37	0.019	.0192072	.2111192
lcapout	-.120044	-2.47	0.015	-.2160001	-.024088
_cons	-.5646316	-11.61	0.000	-.6605876	-.4686756

Table A 11 Regression Results in Stage 2 (Model 6): 99-00

Source	SS	df	MS
Model	1.36610077	7	.195157253
Residual	4.10188637	54	.075960859
Total	5.46798714	61	.089639133

Number of obs	62
F(7, 54)	2.57
Prob > F	0.0232
R-squared	0.2498
Adj R-squared	0.1526
Root MSE	.27561

effw	Coef.	t	P>|t|	[95% Conf.	Interval]
dstate	.0824455	1.12	0.266	-.0645946	.2294855
dyoung	-.0712509	-0.61	0.544	-.3054141	.1629123
dmiddle	-.0448398	-0.49	0.629	-.2297704	.1400907
dsmall	-.2106319	-1.97	0.054	-.424563	.0032991
dmedium	-.0449099	-0.50	0.623	-.2267849	.1369651
downr	.3017038	3.27	0.002	.1168967	.4865109
dru	-.0156147	-0.16	0.872	-.2091823	.1779528
_cons	.5126293	3.59	0.001	.2262958	.7989628

Table A 12 Regression Results in Stage 2 (Model 6):03-04

Source	SS	df	MS
Model	3.22177411	7	.460253445
Residual	13.8082702	229	.060298123
Total	17.0300444	236	.072161205

Number of obs =	237
F(7, 229) =	7.63
Prob > F =	0.0000
R-squared =	0.1892
Adj R-squared =	0.1644
Root MSE =	.24556

effw	Coef.	t	P>|t|	[95% Conf.	Interval]
dstate	.1115472	3.25	0.001	.0438983	.1791961
dyoung	-.1154232	-2.37	0.019	-.2113929	-.0194534
dmiddle	-.0653571	-1.60	0.112	-.1459882	.0152739
dsmall	-.1963382	-4.16	0.000	-.289279	-.1033975
dmedium	-.139725	-3.47	0.001	-.2189576	-.0604923
downr	-.1646584	-2.37	0.019	-.3015819	-.0277349
dru	.0004208	0.01	0.991	-.0736824	.074524
_cons	.9117867	11.13	0.000	.7504293	1.073144

Table A 13 Correlation Matrix: Input Variables used in DEA and Explanatory Variables used in OLS (Scenario 1,1999-2000)

	mat	lab	fcap	wcap	lmatout	lcapout	llabout
lmatout	-0.0440	-0.1022	-0.0443	-0.0356	1.0000		
lcapout	-0.1869	-0.2339	0.3408*	-0.1021	0.0000	1.0000	
llabout	-0.5808*	-0.0780	-0.5257*	-0.2286	0.0000	0.0000	1.0000
lgva	0.5563*	0.7607*	0.5132*	0.3121	0.0000	0.0000	0.0000
dstate	-0.1204	-0.0345	-0.0679	-0.0536	0.0000	0.0000	0.0000
dsmall	0.1568	0.0364	0.2922	0.0266	0.0000	0.0000	0.0000
dmedium	-0.1615	-0.0514	-0.2582	-0.0682	0.0000	0.0000	0.0000
dyoung	-0.1168	-0.0239	0.0819	0.0400	0.0000	0.0000	0.0000
dmiddle	-0.0199	-0.1023	-0.0451	0.1094	0.0000	0.0000	0.0000
downr	0.0606	0.1999	0.0186	0.1774	0.0000	0.0000	0.0000
dru	-0.0644	0.0006	-0.0182	0.2072	0.0000	0.0000	0.0000

	lgva	dstate	dsmall	dmedium	dyoung	dmiddle	downr
lgva	1.0000						
dstate	0.0000	1.0000					
dsmall	0.0000	0.0000	1.0000				
dmedium	0.0000	0.0000	0.0000	1.0000			
dyoung	0.0000	0.0000	0.0000	0.0000	1.0000		
dmiddle	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	
downr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
dru	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A 14 Correlation Matrix: Input Variables used in DEA and Explanatory Variables used in OLS (Scenario 2, 1999-2000)

	mat	lab	fcap	wcap	lgva	lcapout	lmatout
lgva	0.4699*	0.4703*	0.3170	0.2447	1.0000		
lcapout	0.5807*	0.4400*	0.7123*	0.2755	0.0000	1.0000	
lmatout	0.3167	0.3131	-0.1755	0.1597	0.0000	0.0000	1.0000
llabout	-0.1592	0.3702*	-0.1386	-0.0095	0.0000	0.0000	0.0000
lpoll	0.1772	0.1957	0.0641	0.2501	0.0000	0.0000	0.0000
dstate	-0.0929	-0.0029	-0.0583	-0.0133	0.0000	0.0000	0.0000
dsmall	0.1518	0.0302	0.2907	0.0187	0.0000	0.0000	0.0000
dmedium	-0.1522	-0.0397	-0.2560	-0.0533	0.0000	0.0000	0.0000
dyoung	-0.1073	-0.0113	0.0840	0.0561	0.0000	0.0000	0.0000
dmiddle	-0.0155	-0.0963	-0.0440	0.1173	0.0000	0.0000	0.0000
downr	-0.0143	0.1205	0.0016	0.0547	0.0000	0.0000	0.0000
dru	-0.0717	-0.0047	-0.0198	0.1971	0.0000	0.0000	0.0000

	llabout	lpoll	dstate	dsmall	dmedium	dyoung	dmiddle
llabout	1.0000						
lpoll	0.0000	1.0000					
dstate	0.0000	0.0000	1.0000				
dsmall	0.0000	0.0000	0.0000	1.0000			
dmedium	0.0000	0.0000	0.0000	0.0000	1.0000		
dyoung	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	
dmiddle	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
downr	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
dru	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	downr	dru
downr	1.0000	
dru	0.0000	1.0000

Table A 15 Correlation Matrix: Input Variables Used in DEA and Explanatory Variables Used in OLS (Scenario 1, 2003-04)

	fcap	wcap	lab	mat	dstate	dsmall	dmedium
dstate	-0.0307	0.1496	-0.0258	-0.0918	1.0000		
dsmall	-0.2364*	-0.0686	-0.3681*	-0.3108*	0.0000	1.0000	
dmedium	-0.6211*	-0.2070*	-0.6358*	-0.6596*	0.0000	0.0000	1.0000
dyoung	-0.0061	-0.0291	-0.1438	-0.0748	0.0000	0.0000	0.0000
dmiddle	0.0417	-0.0981	-0.2264*	-0.0727	-0.0000	0.0000	0.0000
dru	0.0247	0.0258	-0.1051	-0.0451	0.0000	0.0000	0.0000
downr	0.0525	0.1181	-0.1500	-0.0083	0.0000	0.0000	0.0000
lcapout	0.1662	0.0078	0.0369	-0.0433	0.0000	0.0000	0.0000
lmatout	-0.0412	-0.0498	0.0191	0.1306	0.0000	0.0000	0.0000
llabout	-0.2036*	-0.0901	0.0874	-0.1822	0.0000	0.0000	0.0000
lgva	0.1767	0.0679	0.2885*	0.1655	0.0000	0.0000	0.0000

	dyoung	dmiddle	dru	downr	lcapout	lmatout	llabout
dyoung	1.0000						
dmiddle	0.0000	1.0000					
dru	0.0000	0.0000	1.0000				
downr	0.0000	0.0000	0.0000	1.0000			
lcapout	0.0000	0.0000	0.0000	0.0000	1.0000		
lmatout	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	
llabout	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

Table A 16 Correlation Matrix: Input Variables used in DEA and Explanatory Variables used in OLS (Scenario 2, 2003-04)

	fcap	wcap	lab	mat	dstate	dsmall	dmedium
dstate	-0.0307	0.1496	-0.0258	-0.0918	1.0000	-------	
dsmall	-0.2364*	-0.0686	-0.3681*	-0.3108*	-0.0000	1.0000	
dmedium	-0.6211*	-0.2070*	-0.6358*	-0.6596*	0.0000	0.0000	1.0000
dyoung	-0.0061	-0.0291	-0.1438	-0.0748	0.0000	0.0000	0.0000
dmiddle	0.0417	-0.0981	-0.2264*	-0.0727	0.0000	0.0000	0.0000
dru	0.0247	0.0258	-0.1051	-0.0451	0.0000	0.0000	-0.0000
downr	0.0525	0.1181	-0.1500	-0.0083	0.0000	0.0000	0.0000
llabout	-0.1205	-0.0818	0.0958	-0.1763	0.0000	0.0000	0.0000
lpoll	0.1397	0.0248	0.2596*	0.1832	0.0000	0.0000	0.0000
lgva	0.1037	0.0709	0.1703	0.0241	0.0000	0.0000	0.0000
matout	-0.0398	-0.0221	0.0436	0.1272	0.0000	0.0000	0.0000
lcapout	0.2451*	0.0493	0.0254	0.0585	0.0000	0.0000	0.0000

	dyoung	dmiddle	dru	downr	llabout	lpoll	lgva
dyoung	1.0000						
dmiddle	0.0000	1.0000					
dru	0.0000	0.0000	1.0000				
downr	0.0000	0.0000	0.0000	1.0000			
labout	0.0000	0.0000	0.0000	0.0000	1.0000		
lpoll	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	
lgva	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
lmatout	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
capout	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	lmatout	lcapout
lmatout	1.0000	
lcapout	0.0000	1.0000

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