EFFICIENCY ESTIMATION FOR INDIAN PLASTIC INDUSTRY

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Abstract

Productivity of an industry largely depends on the technical and allocative efficiency of its inputs. Technical Efficiency includes an optimum use of available resources and technology, whereas, Allocative Efficiency deals with how efficiently the available resources are allocated to various alternative uses. Estimation of Technical Efficiency is the main motivation behind the estimation of a Production Frontier. The points below the estimated production frontier are the indicators of Technical Inefficiency.

The present study aims at estimating the Deterministic and Stochastic Production Frontiers to analyze the Technical Efficiency Of Indian Plastic Industry with special reference to Poly Vinyl Chloride (PVC) Plastic since it is the most widely used form of Plastic. Last few decades have experienced a significant growth in Indian Plastic Industry. The study includes Productivity Measurement for Indian PVC Plastic Industry using various Productivity and Performance ratios. It also includes estimation of Deterministic and Stochastic Production Frontiers for the PVC Plastic Industry. The Cobb-Douglas Production Function is used for this purpose since it has been found to be the most appropriate form for Indian Industries from several research studies. Productive Capacity Realization Ratios have been obtained using the Frontier Estimates and thereby the efficiency levels in the PVC Plastic Industry are evaluated. The paper ends with identifying some reasons for the prevailing inefficiency in the industry and some measures to reduce these inefficiencies have been suggested.

Key Words: Efficiency, Deterministic Frontier, Stochastic Frontier, Productivity.

Introduction

Estimation of production function for an economy by OLS provides the estimates of an “average” function, which is associated with mean output for given input levels. The notion of an average function would be more meaningful in a random coefficients model. An average function can then be defined as the function obtained when the random coefficients obtain their expected values. The textbook definition of a production function holds that it gives the maximum possible output which can be produced from the given quantities of a set of inputs. In such a case the word “frontier” may be meaningfully applied because the function sets a limit to the range of possible observations. From an econometric view point, the estimation of frontiers is interesting because the concept of maximality (or minimality in case of costs) puts a bound on dependent variable. One may observe the points below the frontier as the indicators of inefficiency. Thus, the measurement of inefficiency has been the main motivation of the study of frontiers.

Plastic Industry

Plastic is the general common term for a wide range of synthetic or semi synthetic organic amorphous solid materials suitable for the manufacture of industrial products. Plastics are typically polymers of high molecular weight, and may contain other substances to improve performance and/or reduce costs.

The word derives from the Greek *πλαστικός* (plastikos) meaning *fit for molding*, and *πλαστός* (plastos) meaning *molded*. It refers to their malleability, or plasticity during manufacture, that allows them to be cast, pressed, or extruded into an enormous variety of shapes—such as films, fibers, plates, tubes, bottles, boxes, and much more.

The common word *plastic* should not be confused with the technical adjective *plastic*, which is applied to any material which undergoes a permanent change of shape (plastic deformation) when strained beyond a certain point. Aluminum, for instance, is plastic in this sense, but not a plastic in the common sense; in contrast, in their finished forms, some plastics will break before deforming and therefore are not plastic in the technical sense.

One of the most impressive plastics used in the war, and a top secret, was "polytetrafluoroethylene" (PTFE), better known as "Teflon," which could be deposited on metal surfaces as a scratchproof and corrosion-resistant, low-friction protective coating. The polyfluoroethylene surface layer created by exposing a polyethylene container to fluorine gas is very similar to Teflon. One of the most visible parts of this plastics invasion was Earl Tupper's "Tupperware," a complete line of sealable polyethylene food containers that Tupper cleverly promoted through a network of housewives who sold Tupperware as a means of bringing in some money. The Tupperware line of products was well thought out and highly effective, greatly reducing spoilage of foods in storage. Thin-film "Plastic wrap" that could be purchased in rolls also helped keep food fresh.

Another prominent element in 1950s homes was "Formica," a plastic laminate that was used to surface furniture and cabinetry. Formica was durable and attractive. It was particularly useful in kitchens, as it did not absorb, and could be easily cleaned of stains from food preparation, such as blood or grease. With Formica, a very attractive and well-built table could be built using low-cost and lightweight plywood with Formica covering, rather than expensive and heavy hardwoods like oak or mahogany.

Composite materials like fiberglass came into use for building boats and, in some cases, cars. Polyurethane foam was used to fill mattresses, and Styrofoam was used to line ice coolers and to make float toys.

Plastics continue to be improved. General Electric introduced "Lexan," a high-impact "polycarbonate" plastic, in the 1970s. Du Pont developed "Kevlar," an extremely strong synthetic fiber that was best-known for its use in bullet-proof vests and combat helmets. Kevlar was so remarkable that Du Pont officials actually had to release statements to deny rumors that the company had received there cipeforit from space aliens.

Plastics can be classified by their chemical structure, namely the molecular units that make up the polymer's backbone and side chains. Some important groups in these classifications are the acrylics, polyesters, silicones, polyurethanes, and halogenated plastics. Plastics can also be classified by the chemical process used in their synthesis; e.g., as condensation, polyaddition, cross-linking, etc.

Other classifications are based on qualities that are relevant for manufacturing or product design. Examples of such classes are the thermoplastic and thermo set, elastomer, structural, biodegradable, electrically conductive, etc. Plastics can also be ranked by various physical properties, such as density, tensile strength, glass transition temperature, resistance to various chemical products, etc.

Due to their relatively low cost, ease of manufacture, versatility, and imperviousness to water, plastics are used in an enormous and expanding range of products, from paper clips to spaceships. They have already displaced many traditional materials, such as wood; stone; horn and bone; leather; paper; metal; glass; and ceramic, in most of their former uses.

Research Methodology

The present study aims at estimating the Deterministic and Stochastic Production Frontiers to analyze the Technical Efficiency of Indian Plastic Industry with special reference to Poly Vinyl Chloride (PVC) Plastic since it is the most widely used form of Plastic. Last few decades have experienced a significant growth in Indian Plastic Industry.

Time-series data for last 10 years from 2000-01 to 2009-10 is chosen for Poly Vinyl Chloride (PVC) Plastic Industry as a whole. Database includes the variables such as Production (Output), Revenue, Capital and Labor for the present study. **“Centre for Monitoring Indian Economy” (CMIE) & “Annual Survey of Industries” (ASI)** form the backbone of the database used for the study. The study is based upon the methodology of estimating Deterministic and Stochastic Frontiers as suggested by Aigner et. al. [1977].

Methodology of Deterministic Frontier Estimation

Richmond [1974], based on the Ordinary Least Squares (OLS) results suggested a method known by COLS (Corrected Least Squares) method. From several empirical studies, linear Cobb-Douglas (CD) model has been found to be the best form of production function for Indian Industries and hence we have chosen this model for present study. Thus, our model is

$$\ln y = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln x_i - u_i \text{ , } u \geq 0 \qquad \text{eq.(1)}$$

Then if we let μ be the mean of u, we can write

$$\ln y = (\alpha_0 - \mu) + \sum_{i=1}^{n} \alpha_i \ln x_i - (u - \mu) \qquad \text{eq.(2)}$$

where the new error term has zero mean. This error term satisfies all of the usual ideal conditions except normality. Therefore eq.(2) may now be estimated by OLS to obtain best linear unbiased estimates of $(\alpha_0 - \mu)$ and of the α_i's. If a specific distribution is assumed for u, and if the parameters of this distribution can be derived from its higher-order (second, third, etc.) central moments, then can estimate these parameters consistently from the moments of the OLS residuals. Since μ is a function of these parameters, it too can be estimated consistently, and this estimate can be used to correct the OLS constant term, which is a consistent estimate of $(\alpha - \mu)$. COLS method thus provides consistent estimates of all the parameters of the frontier. A difficulty with the COLS technique is that, even after correcting the constant term, some of the residuals may still have wrong sign so that these observations end up above the estimated production frontier. This makes the COLS frontier a somewhat awkward basis for computing the technical efficiency of individual observations. One response to this problem is provided by the Stochastic Frontier approach discussed in the next section.

Another way of resolving the problem is to estimate eq.(1) by OLS, and then to correct the constant term not as above, but by shifting it up until no residual is positive and one is zero. Gabrielson [1957] and Green [1980] have both shown that this correction provides a consistent estimate of α_0.

Another difficulty with the COLS technique is that the correction to the constant term is not independent of the distribution assumed for u. Considering the one-parameter Gamma distribution for u, (**COLS I**), we have

$$g_1(u,\sigma) = \frac{1}{\Gamma(\sigma)}(u)^{\sigma-1}\exp(-u) \qquad 0 < u < \infty, \quad \sigma > 0 \qquad \text{eq.(3)}$$

The first two moments are E(u) = V(u) = σ. Hence the OLS variance estimator provides the correction to the constant term. Now considering the exponential distribution for u, **(COLS II)**, we have

$$g_2(u,\sigma) = (1/\sigma)\exp(-u/\sigma) \qquad 0 < u < \infty, \quad \sigma > 0 \qquad \text{eq.(4)}$$

with first two moments E(u) = σ, V(u) = σ^2. Hence the positive square root of the OLS variance estimator provides the correction to the constant term. Thus the one-parameter Gamma distribution yield systematically different estimates of technical efficiency, except for the special case V(u) = 1.

Methodology of Stochastic Frontier Estimation

The notion of a deterministic frontier shared by all firms ignores the very real possibility that a firm's performance may be affected by factors entirely outside its control such as poor machine performance, bad weather and input supply breakdowns and so on, as well as by factors under its control (inefficiency). To lump the effects of exogenous shocks, both fortunate and unfortunate, together with the effects of measurement error and inefficiency into a single one-sided error term, and to label the mixture "*inefficiency*" is somewhat questionable. This conclusion is reinforced if one considers also the statistical "*noise*" that every empirical relationship contains. The standard interpretation is that first, there may be measurement error (hopefully on the dependent variable and not on the independent variables). Secondly, the equation may not be completely specified (hopefully with the omitted variables individually unimportant). Both of these arguments hold just as well for production functions as for any other kind of equation and it is dubious at best not to distinguish this "noise" from inefficiency or to assume that "noise" is one-sided. Thus, a stochastic frontier uses a mixture of one-sided and two-sided errors. Thus, given quantities of a list of inputs, there is a maximal output that is possible but this maximal level is random rather than exact. This assumes that some other inputs or external effects, but others have potentially unbounded effects. Thus, the stochastic frontier expresses maximal output, given some set of inputs, as a distribution rather than a point. These arguments lie behind the stochastic frontier, also called "*composed error*" model as given by Aigner et.al. [1977], Meeusen and Van Den Broeck [1977]. The essential idea behind the stochastic frontier model is that the error term is composed of two parts. A symmetric component permits random variation of the frontier across firms and captures the effects of measurement error, other statistical "*noise*" and random shocks outside the firm's control. A one-sided component captures the effects of inefficiency relative to the stochastic frontier. A stochastic production frontier model may be written as:

$$y = f(x)\ \exp\ (\nu - u) \qquad \text{eq.(5)}$$

where the stochastic production frontier f(x) exp (ν), ν having same symmetric distribution to capture the random effects of measurement error and exogenous shocks which cause the placement of the deterministic kernel f(x) to vary across firms. In our case f(x) is the Cobb-Douglas Production function. Technical inefficiency relative to the stochastic production frontier is then captured by the one-sided error component $\exp(-u), \quad u \geq 0$. The condition $u \geq 0$ ensures that all observations lie on or beneath the stochastic production frontier. Unfortunately there is no way of determining whether the observed performance of a particular observation compared with the deterministic kernel of the frontier is due to inefficiency or to random variation in the frontier. This constitutes the main weakness of the stochastic frontier model; it is not possible to estimate technical inefficiency by observation. The best that one can do is to obtain an estimate of mean inefficiency over the sample.

Direct estimates of the stochastic production frontier model may be obtained by either maximum likelihood or (OLS methods). Introducing specific probability distributions for ν and u, assuming that u and ν are independent and that x is exogenous, the asymptotic properties of the maximum likelihood estimators can be proved in the usual ways. The model may also be estimated by COLS adjusting the constant term by E(u), which is derived from the moments of the OLS residuals. The COLS estimates are easier to compute than the maximum likelihood estimates, although they are asymptotically less efficient. Olson et. al. [1980] presents the evidence which indicates that COLS generally performs as well as maximum likelihood, even for rather large sample sizes. Whether the model is estimated by maximum likelihood or COLS, the distribution of u must be specified.

For a linear production model in the usual matrix form

$$\underset{N*1}{y} = \underset{N*k}{X}\,\underset{k*1}{\beta} + \underset{N*1}{\varepsilon} \qquad \text{eq. (6)}$$

Where y and ε are N*1 vectors of observations of output and the random disturbance respectively; X is an N*k matrix of observations on the constant term and k-1 inputs and β is a k*1 vector of parameters; the error specification is

$$\varepsilon = v - u \qquad \text{eq.(7)}$$

where, the elements of y are i.i.d. as $N\left(0, \sigma_v^2\right)$, while the elements of u are absolute values of the variables which are i.i.d. as half normal, as suggested by *Aigner, Lovell and Schmidt (1979)*.
All v's and u's are independent of each other and are also independent of X. A convenient reparameterization of the disturbance specification suggested by *Aigner, Lovell and Schmidt (1979)* is

$$\sigma^2 = \sigma_u^2 + \sigma_v^2, \; \lambda = \sigma_u / \sigma_v \qquad \text{eq.(8)}$$

Here we consider the estimator by COLS method. For this purpose we begin with the OLS estimator $\hat{\beta} = \left(X'X\right)^{-1} X'y$. Except for the constant term, the OLS estimator is unbiased and consistent; its covariance matrix is equal to $\sigma_\varepsilon^2 \left(X'X\right)^{-1}$ where $\sigma_\varepsilon^2 = \text{variance of } \varepsilon$. The bias of the constant term is the mean of ε; $\hat{\mu} = \left(-2/\pi\right)\hat{\sigma}_u$. The variances of σ_u^2 and σ_v^2 can be consistently estimated by

$$\hat{\sigma}_u^2 = \left[\frac{\pi}{2}\left[\frac{\pi}{\pi - 4}\right]\hat{\mu}'_3\right]^{2/3}$$

and

$$\hat{\sigma}_v^2 = \hat{\mu}_2{}' - \frac{\pi - 2}{\pi}\hat{\sigma}_u^2. \qquad \text{eq.(9)}$$

where $\hat{\mu}_2{}'$ and $\hat{\mu}_3{}'$ are the second and third moments of the OLS residuals. The constant term is then corrected by adding to the OLS estimated constant term the negative of the estimated bias, $\left(2/\pi\right)\hat{\sigma}_u$.

Frontier Estimation for Plastic Industry

For our purpose of study we have estimated the Deterministic and Stochastic Frontiers for Plastic Industry with special reference to Poly Vinyl Chloride (PVC) Plastic. Deterministic and Stochastic Frontier Estimation resulted in some positive residuals after correcting the constant term. For solving this problem we further improved the frontier estimates by shifting the constant term up until no residual is positive and one is zero, as suggested by *Forsund (1980)*. The results of Frontier estimation by COLS-I, COLS-II and Stochastic frontier methodologies are summarized in the **Table:1** below:

Table:1 Parameter Estimates For Production Frontiers

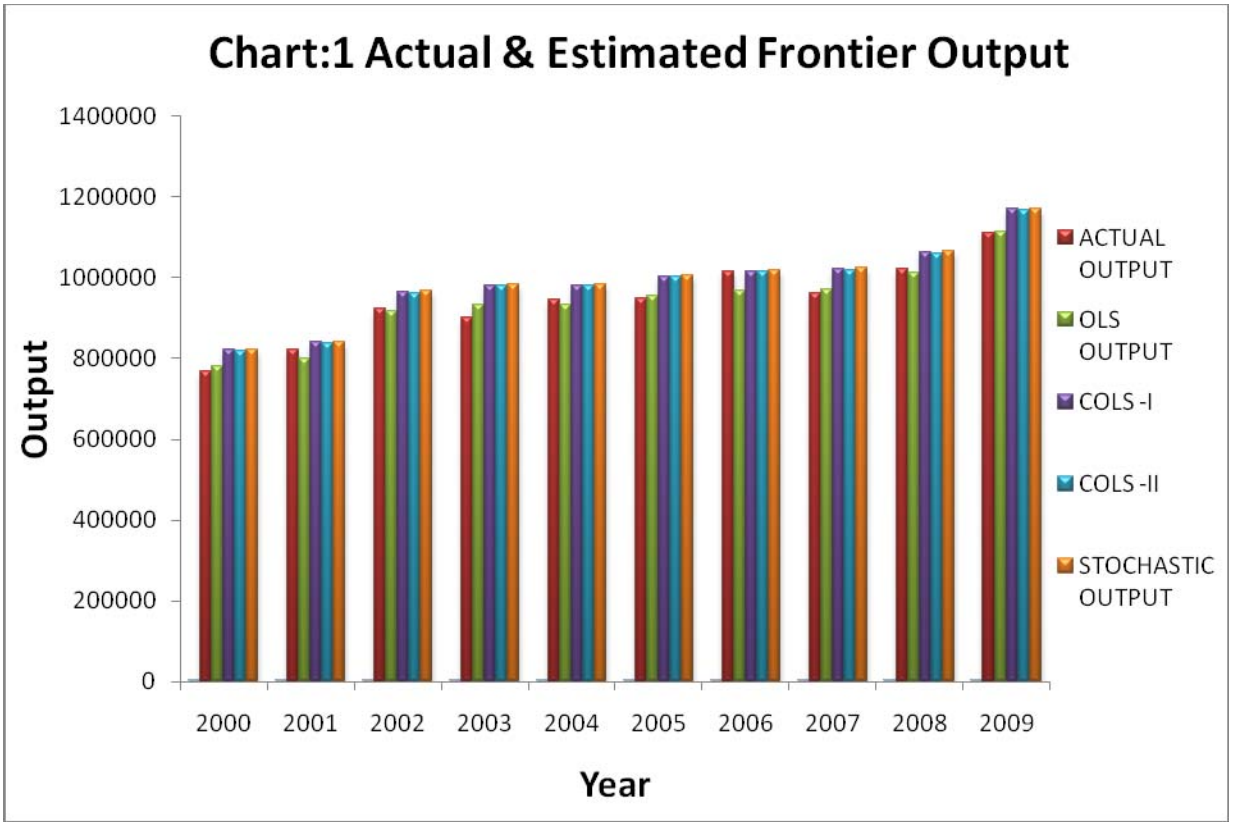
	OLS	COLS-I	COLS-II	STOCHASTIC
Constant	12.87	12.9195	12.91785	12.85203
Capital	0.193	0.193	0.193	0.193
Labor	-0.122	-0.122	-0.122	-0.122
R-Squared	0.947			

The Actual and Estimated output for production frontiers by above methods are summarized in the **Table:2** below:

Table:2 Actual and Estimated Frontier Output

YEAR	ACTUAL OUTPUT	COLS I	COLS II	STOC. OUTPUT
2000	768700	821305.5035	819952.5368	823386.0372
2001	821463	839920.673	838537.0409	842048.3627
2002	922715	964257.2955	962668.8391	966699.9551
2003	901866	981047.826	979431.7099	983533.0194
2004	945830	982021.2351	980403.5155	984508.8944
2005	948768	1004166.618	1002512.417	1006710.376
2006	1014685	1016359.286	1014685	1018933.93
2007	961041	1022030.169	1020346.542	1024619.179
2008	1020700	1062505.351	1060755.047	1065196.893
2009	1112615	1169847.641	1167920.508	1172811.102

Actual vs. Estimated Frontier Output by all the methods are represented by Bar Chart as in **Chart:1**



The above Chart indicates that the Actual Output has almost an increasing trend over the years. There is significant difference between Actual and Estimated Output by COLS-I, COLS-II and Stochastic methods, which indicates the scope of efficiency improvement in Plastic Industry.
There are several measures of production performance evaluation, but a relevant measure in the context of productivity analysis is the **P**roductive **C**apacity **R**ealisation(PCR) which is defined as "*the ability of the Industry to obtain the maximum possible output from a given set of inputs and technology*". This is an important "*benchmark*" because it indicates that the central objective of any Industry should be to produce the maximum possible output from a given set of inputs so that there is no wastage of resources. Thus, the difference between actual output and estimated frontier output (potential output) indicates the inefficiency of the industry.

In order to measure Technical Efficiency for Plastic Industry, Productive Capacity Realisation (PCR) Ratios are computed as under :

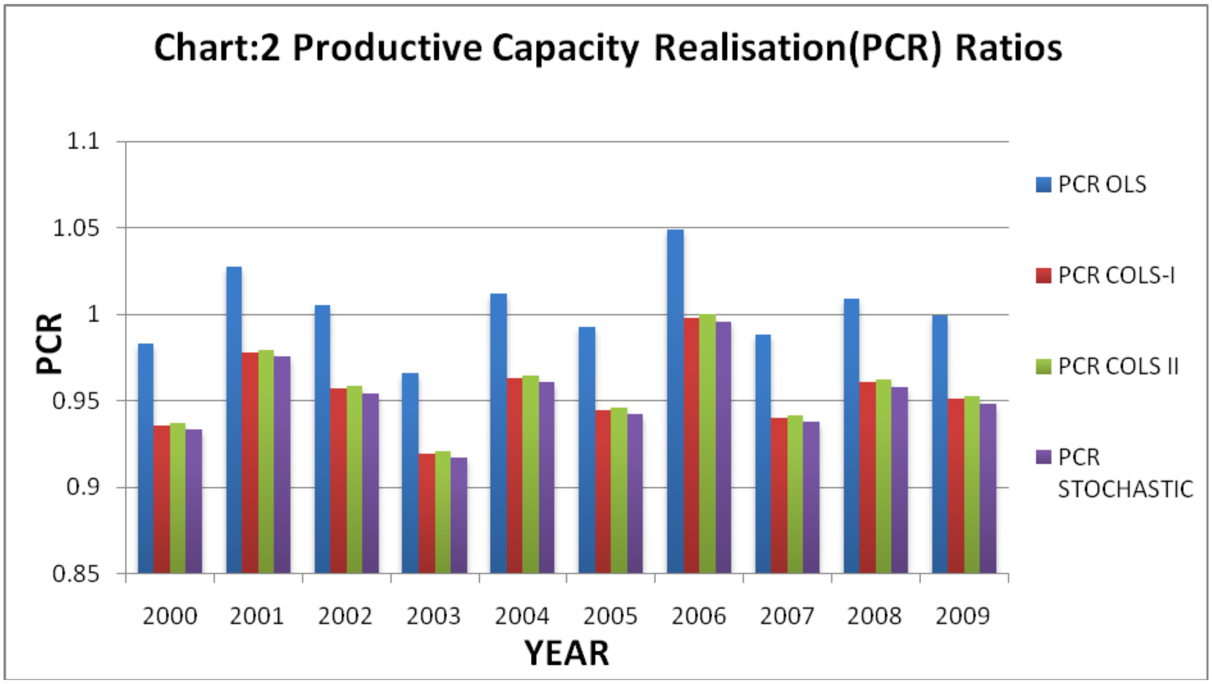
$$PCR = \frac{\text{Realised Output}}{\text{Potential Output}} \qquad \text{eq.(10)}$$

The PCR Ratios for OLS, COLS-I, COLS-II and Stochastic Frontiers have been computed and are summarized in **Table:3** below:

Table:3 Productive Capacity Realisation (PCR) Ratios

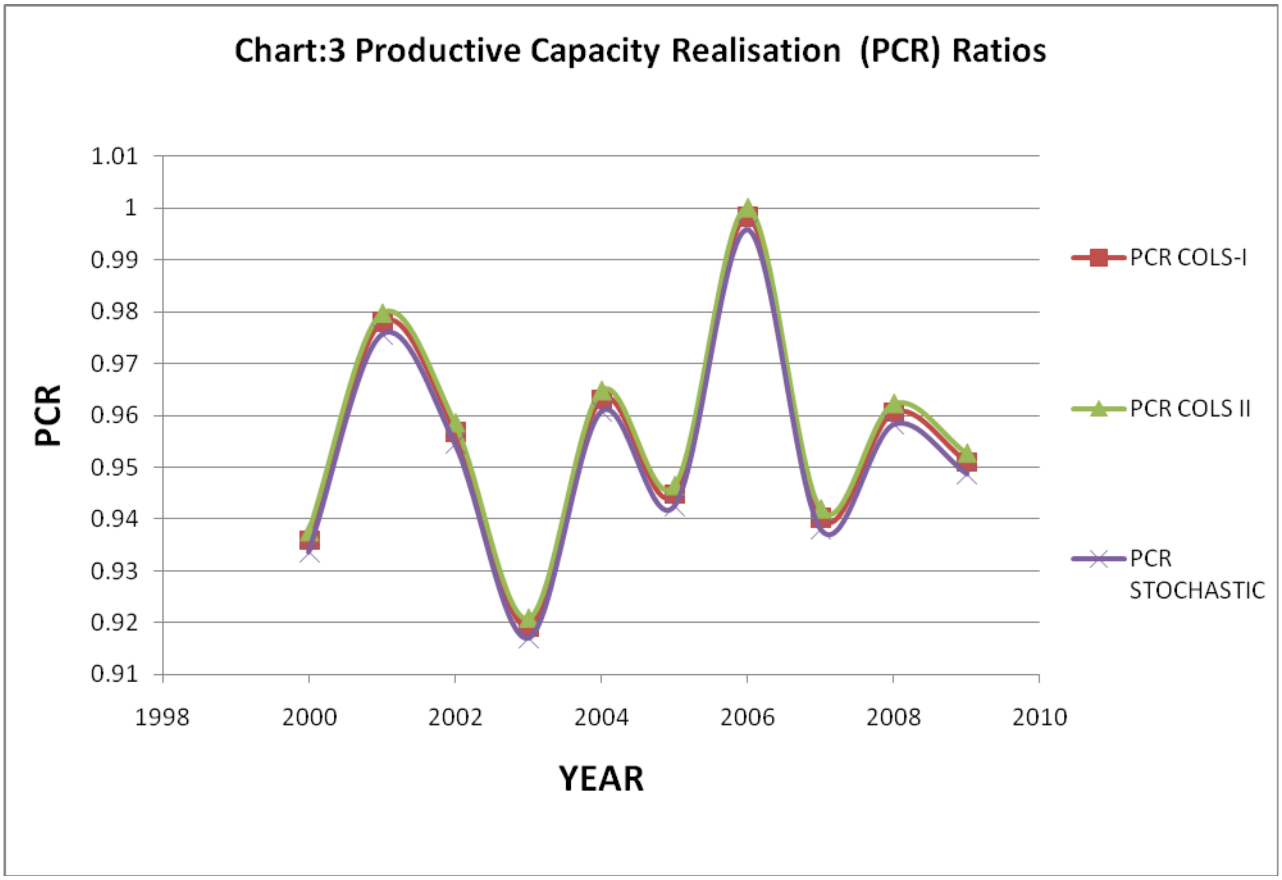
YEAR	PCR OLS	PCR COLS-I	PCR COLS II	PCR STOCHASTIC
2000	0.9834	0.9359	0.9375	0.9336
2001	1.0277	0.9780	0.9796	0.9756
2002	1.0055	0.9569	0.9585	0.9545
2003	0.9659	0.9193	0.9208	0.9170
2004	1.0120	0.9631	0.9647	0.9607
2005	0.9928	0.9448	0.9464	0.9424
2006	1.0490	0.9984	1.0000	0.9958
2007	0.9880	0.9403	0.9419	0.9379
2008	1.0094	0.9607	0.9622	0.9582
2009	0.9993	0.9511	0.9526	0.9487
Average	**1.0033**	**0.9549**	**0.9564**	**0.9524**

PCR Ratios obtained above have been plotted in **Chart:2**, in order to compare year wise Technical Efficiency by all methods.



PCR Ratios obtained by OLS indicate that output observations lie above as well as below the estimated straight line. But the concept of frontier defines all the observations to be below or on the estimated frontier. Hence PCR ratios must be less than or equal to one for all the observations for the estimated frontier. The above **Table:2** and **Chart:2** shows year wise PCR ratios with average 95% efficiency by all the three estimated frontier models. This indicates good performance of PVC Industry during the last decade.

Chart:3 below indicates the trend of PCR ratios for estimated frontiers. Efficiency estimates for all the three estimated frontiers almost coincide with each other. The last decade has faced many fluctuations in the efficiency levels of Plastic industry.



The efficiency level has increased significantly from about 93% in year 2000 to 98% in 2001. Then after there is a tremendous fall in efficiency to about 92% in year 2003 due to the changes in macro economic factors such as crude oil price, dollar value in the international market, growing competition, raw material prices, government policies, etc. After year 2003 till year 2006 the industry has experienced a significant rise in efficiency and has been able to reach the highest efficiency level of "*one*" in year 2006. Again there was a sudden downfall in the capacity utilization level to about 94% in year 2007 due to the impact of Global Recession. The industry has been able to revive itself to the efficiency level of about 96% in the year 2008 with a subsequent fall in year 2009.

Overall the Industry Capacity Utilization Level varies between 91% to 100%, over the period. The fall of efficiency in year 2009 is an alarming situation for the Industry, indicating the scope of improvement in productivity.

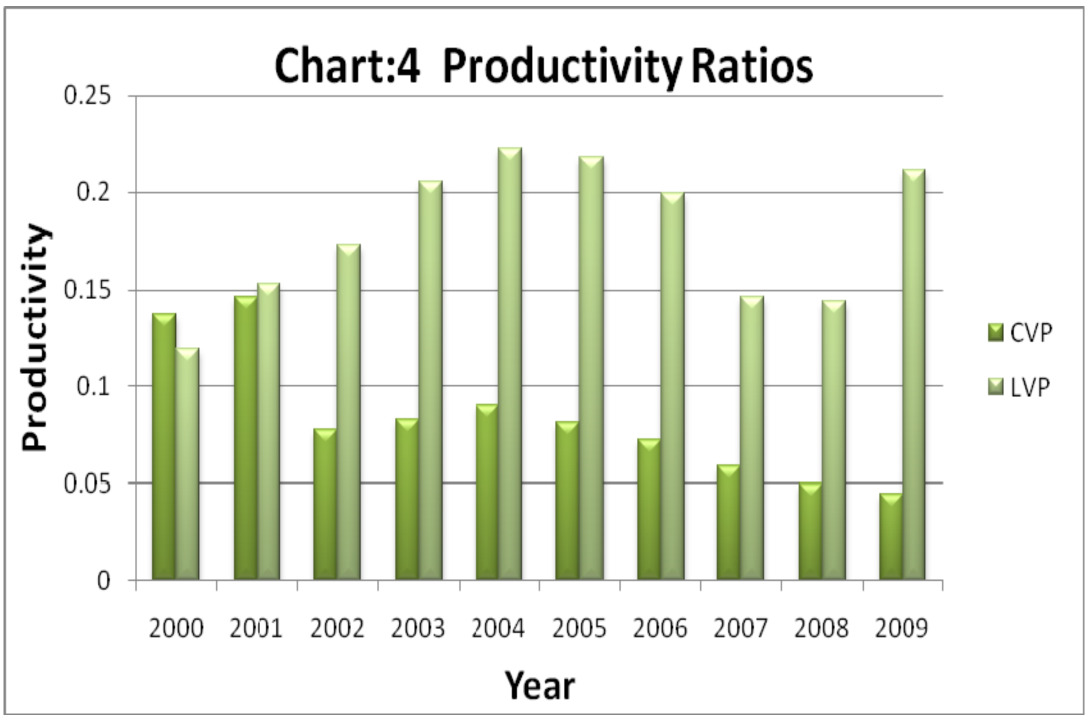
In order to analyze the reasons for prevailing "*Inefficiency*" we have calculated the following **Input Productivity Indices**:

- **Labor Value Productivity (LVP) = Total Revenue/Total Labor Input.** eq.(11)
- **Capital Value Productivity (CVP) = Total Revenue/Total Capital Input**. eq.(12)

The above productivity ratios are summarized in **Table:4** below and are plotted in **Chart:3** below:

Table:4 Productivity Ratios

YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
CVP	0.1370	0.1461	0.0773	0.0827	0.0903	0.0811	0.0722	0.0587	0.0500	0.0447	**0.0840**
LVP	0.1190	0.1529	0.1731	0.2055	0.2225	0.2181	0.1992	0.1460	0.1441	0.2114	**0.1792**



This Chart indicates that Labor productivity is higher than Capital productivity over the period except for the year 2000. From year 2002 onwards Capital productivity is significantly less than that of Labor indicating underutilization of capital throughout the period. This clearly shows that there is an urgent need of devising strategies for proper utilization of capital such as concentric or conglomerate diversification, expansion of the product line, backward or forward integration, adopting world class technologies of production, etc. Average Labor productivity is 17.92% as against only 8.4% Average Capital productivity. Again these figures also indicate that Revenue generation in PVC Industry largely depends upon other external and internal factors apart from labor and capital. Thus the industry needs to pay more attention towards these factors for increasing Total Value Productivity. Strategies that can contribute towards proper utilization of capital in managing these other external and internal factors must be adopted in order to increase the Efficiency levels.

Summary and Conclusions

We conclude the paper with the following important findings and conclusions:

- Both Deterministic and Stochastic Frontier estimation provide 95% average efficiency of PVC Plastic Industry supporting the growth of this Industry during the last decade.
- The Industry has been able to achieve perfect efficiency level in year 2006.
- There is a fall in efficiency in the year 2009 which is an alarming situation for PVC Industry.
- The PCR Ratios indicate that there is a scope for further efficiency improvement in this Industry.
- Capital Underutilization has been clearly pointed out by the Productivity Ratios.
- Major factors such as crude oil price, dollar value in the international market, growing competition, raw material prices, government policies, etc. greatly affect the performance of this Industry.
- There is an urgent need of adopting Strategies for improving Technical Efficiency and proper Capital Utilization, such as concentric or conglomerate diversification, expansion of the product line, backward or forward integration, adopting world class technologies of production, etc.

Limitations and Further Scope of Research

The present study is based upon the limited data set of Output, Labor, Capital and Revenue of only the last decade. Other variables such as crude oil price, dollar value in the international market, growing competition, raw material prices, government policies, etc. can also be included for efficiency estimation and overall performance evaluation of this Industry. Performance of Indian PVC Industry can be compared with the world class PVC companies and the Strategies adopted by these companies must be evaluated in Indian perspective. Other models of Performance evaluation such as Cluster Analysis, Scaling Models and Discriminant Analysis can be employed including both Quantitative as well as Qualitative Performance Indicators.

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