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EFFICIENCY OF INDIAN FERTILIZER FIRMS: A STOCHASTIC FRONTIER APPROACH

Soumita Khan*

Abstract

This paper examines the competitiveness of Indian fertilizer firms by computing their output oriented technical efficiency from 1993-94 to 2012-13, using the stochastic frontier approach. It reveals that the industry runs at 57 percent technical efficiency on an average and that there is scope for further improvement. The research also finds that the private sector fertilizer firms are more efficient than the public sector ones. In addition, it reveals that large and experienced firms are more efficient than small and new firms. This analysis concludes that the current level of R&D expenditure or imports do not improve the efficiency levels, especially in the short run. However, in the long run, R & D may play a crucial role in improving efficiency as in any manufacturing sector. The public firms can enter into technological collaborations with private firms to gain higher efficiency. The large number of technological collaborations noticed in this sector in recent times, therefore, is a welcome development.

Keywords: *Stochastic production, Technical efficiency, Fertilizer, Efficiency factors.*

JEL Classifications: *D21, D22, Q20, L660.*

Introduction

Fertilizer industry forms the backbone of India's agricultural sector in ensuring sufficient food grain production. We need to have a well-fed nation so that people are able to use their time and potential productively with a healthy life. Unfortunately, a very large proportion of population (out of 1.2 billion) goes without food for social, economic or other reasons. The use of fertilizers facilitates faster foodgrain production as compared to organic means. Instead of getting into a scholarly argument on whether organic farming or fertilizer-based farming is good, what is important to note is that for a large proportion of the population, food in itself is very scarce and hence, fertilizer production is very important for more than 50 percent of our population in need of food. Thus, fertilizer assumes great significance in feeding the nation with a population of 1.2 billion. So, given the significance of fertilizers in foodgrain production, achieving efficiency in this sector becomes an important issue since improved efficiency in fertilizer production can help reduce the magnitude of hunger among the populace to a large extent. Like any other manufacturing industry, proper usage of inputs may have a significant impact on output growth or efficiency. Going by the *Fertilizer Association of India (FAI), 2011-12* report, the Indian fertilizer sector has witnessed consistent growth over time, especially post 2000. A study by Mongia (1998) on India's fertilizer industry shows that there is an upward trend for all inputs related to labour and capital productivities while an opposite trend is seen in respect of material and energy

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inputs. This indicates that India's fertilizer sector is less labour and capital intensive in relation to energy and materials.

Regarding the domestic scenario, the production of fertilizers is carried out through a combination of public and private sector enterprises. According to the *Centre for Monitoring of Indian Economy (CMIE) Report 2012-13*, there are about 68 large and 72 medium and small fertilizer units in India. Among the large units, 47 plants are under private entrepreneurs, 18 under public entrepreneurs and 3 under co-operative entrepreneurs. Although the number of public enterprises is less at 18, they control the major share of production in this industry. Each and every firm also differs in terms of their share in production, consumption, savings, market allocation and other attributes. Thus, to understand the best possible outcome it is important to compare all fertilizer firm categories and from them, identify the most efficient fertilizer firms. If we are able to identify the most efficient firm/s, other firms may get enthused to follow the best practices so that the sector as a whole will benefit. Also, more efficient production of fertilizers can help reduce the overall subsidy bill (assuming that less subsidy will be needed if the sector becomes more efficient). Right now, about 0.5 percent of the overall GDP of our country is spent on fertilizer subsidy (from the Report of Government on subsidies, IOSR, 2015) and an improved efficiency in this sector can certainly reduce this subsidy burden for the country.

However, technology itself can bring about performance differentials among fertilizer firms; with a proper technology in place, firms can produce more output by utilization of their currently available inputs. Besides, India's fertilizer industry has kept pace with technological developments at the global level through up-gradation and utilization of better feedstock. As mentioned before, subsidy is an important component that substantially influences the fertilizer sector. Of the inputs, 'material' and 'energy' continue to be highly subsidized. Within manufacturing, the fertilizer sector specially enjoys a lot of subsidy benefit. But, economic theory tells us that state supports like subsidies often tend to make producers less competitive and more lax. Thus, subsidization may be increasing inefficiencies among fertilizer firms.

In any efficiency-related literature, there exist two ways of measuring the efficiency of firms, namely, the output efficiency that captures how far an inefficient firm can increase its output to reach the frontier with the level of inputs it incorporates, and the input efficiency that identifies how far a firm can reduce its input usage for a given level of output it produces. Most of the previous studies related to manufacturing industries, such as the one by Lovell (1993), have either given a higher weightage to the output expansion of firms for computing their output efficiency or have computed the input efficiency by minimizing the levels of input usage. Thus, in efficiency analysis, it is assumed that all firms may not be able to carry out their objectives in the most optimal manner even when they operate in a similar environment. Most efficient firms within a particular industry operate on the frontier, which is the envelope, and researchers are interested in finding out that particular combination of inputs used by these firms and the resultant output, which together make them the most efficient ones within a given industry. Therefore, given the estimated production frontier (which is arrived at by enveloping the input-output bundles of the best performing firms), there can be a gap in the output produced by any particular firm relative to the frontier, which indicates the level of inefficiency achieved by this firm.

When we are talking about efficiency, we need to find out more about the factors that drive these efficiencies. Among the literature, studies by Majumder (2012) (in particular) and by Sharma (2009) help us to identify the factors influencing the efficiency of firms. We observe in these studies that estimated efficiency scores for a given set of firms are related to a number of strategic variables. A two-limit tobit regression is applied here where ownership structure, size, experience, technology, and capital intensity are considered as significant factors. Without incorporating the policy side, any analysis becomes incomplete, especially for the fertilizer sector, since it is fully controlled by the Government, where subsidy plays a vital role in the estimation of a firm's efficiency. Trade-related variables like export-import also affect a firm's efficiency level.

Fertilizer as an issue has been studied by researchers more as an input in the agricultural production process rather than as an output. Also, the efficiency-related performance analysis for Indian fertilizer firms has not received enough attention before. Thus, in view of this unique characteristic of being a critical input in foodgrain production, supported by a considerable subsidy, this sector makes for an interesting study area.

This paper unfolds in the following manner. The next section discusses reviews related to the study, followed by a section on methodology. Data sources used for an empirical exercise are presented in the next section. Finally, empirical results are presented, followed by conclusions.

Empirical Literature on Technical Efficiency of Indian Manufacturing Sector in General

As far as the technical efficiency measurement of Indian manufacturing sector is concerned, a flurry of research has been carried out in this area. Here, some of the studies are presented in brief.

Many studies exist on the traditional measurement of technical efficiency.

There are two approaches to a frontier analysis: one is the parametric stochastic frontier approach (SFA) and the other is the non-parametric data envelopment approach (DEA).

Kalirajan (1981) was the first one to have used SFA, followed by a large number of economists later. Papers by Kumbhakar (1991), Coelli (1992) and others use SFA for estimating technical inefficiency effects with its parameters. Coelli's (1992) study measures technical inefficiency, which involves both farmer-specific variables and time. Some of the parametric-based studies related to efficiency analyses include Neogi (1994), Kathuria (2000), Kalirajan (2005) etc. Among them, Neogi (1994) concludes that globalization has a negative impact on a firm's technical efficiency. This study also gives an idea of the factors causing inter-firm variations in efficiency in terms of quality of labour, capital investment, profit etc. As the study observes, higher quality labour leads to increased efficiency in a given firm's production while the same may reduce capital intensity with a (resultant) negative impact on efficiency. The study by Kalirajan (2005) was the first to use the random coefficient model developed by Swamy (1971) in estimating the efficiency of the Indian manufacturing sector. This study indicates that post liberalization, productivity growth in the manufacturing sector had slowed down, resulting in a

downward trend in technical efficiency. The impact of liberalization on the efficiency gain of Indian manufacturing firms has also been studied by Kathuria (2000), using SFA.

Among the various factors affecting efficiency, firm size was considered by Goldar (1985) in examining the relationship between size and economic efficiency with respect to the soap industry of India. Applying SFA, the study estimated the mean technical efficiency at 47 percent. It also found tiny units were quite inefficient relative to the bigger units within the industry, thereby indicating a positive relationship between the two. Goldar's (2004) study, while examining the ownership structure and efficiency with reference to engineering firms over the period 1990 to 2000, found foreign firms to have higher efficiency as compared to domestic firms in India. There are also indications of domestic firms merging with foreign firms to improve technical efficiency. This merging process also has been observed in the case of Indian fertilizer firms. Many small and tiny fertilizer firms have been merged with larger ones, especially post 2000, to improve competitiveness and ensure their survival. On the basis of this argument, a study by Mandal (2009) while measuring the technical efficiency using the decomposition method in respect of Indian cement industry, found the growth in productivity being driven mainly by the scale component and technical progress, and not by a technical efficiency change. This decomposition method is a useful tool in measuring the sources of productivity growth directly.

Apart from SFA technique, Charnes (1978) was the first one to have presented the DEA model. A study by Ray (2002) found a declining trend in the average efficiency of the Indian manufacturing sector between 1991 and 1996 and thereafter. This approach was employed in examining the dynamics of efficiency prevalent in different states and was followed by Mukherjee (2004). While examining the impact of ownership pattern on efficiency for eight different sectors, Rammohan's (2003) study found that only for chemical, iron and textile industries, the private sector's technical efficiency scores were superior while for electronics and services, the public sector's scores were superior; for minerals, and transport, no difference was observed relative to their ownership patterns. Nikaido (2004) also analyzed the falling trend in the efficiency of small-scale industries (SSI) using all India census data on small-scale units for 1992. This study concluded that, on average, SSIs were operating at 80 percent of the potential maximum production frontier with the firm size negatively affecting their efficiency. A study with DEA by Majumder (2012) also examined the competitiveness of Indian pharmaceutical firms by computing their technical efficiency for the period 1991 to 2005. The analysis reveals a declining trend in output efficiency besides identifying the determinants of technical efficiency. It should be noted here that the DEA approach suffers from measurement errors with respect to the shape and positioning of the estimated frontier in the absence of particular functional forms. Thus, compared to DEA, the SFA approach appears more flexible when it comes to measuring the technical efficiency of firms.

Reviews on Indian Fertilizer Sector

Most of the studies dealing with the fertilizer sector consider fertilizer as an input in their analyses rather than as an output. It is important to note here that the usage of fertilizer in agricultural

production has shown an increasing trend, especially after the green revolution. However, to maximize agricultural production from a given unit of area, the use of optimum fertilizer doses with other inputs is very necessary. Of the existing literature, studies by Singh (1976), Mehta (1982), Shobti (1983), Subharao (1985) etc. have attempted to analyze the extent of fertilizer use and its impact on productivity of firms in the Indian context. It is to be noted that all these studies mentioned above incorporate fertilizer as an input in agriculture. Also, most of the works above are based on the traditional growth accounting approach. The relevant efficiency related questions based on the frontier approach have not been adequately addressed with respect to the fertilizer sector in India.

Given these gaps, the objective of the present study is to concentrate on output efficiency measurement in the context of Indian fertilizer firms and to identify the determinants of efficiency. The study employs the stochastic parametric frontier approach for estimating directly the technical efficiency of firms.

Methodology Related to the Study

Following economic theory, one of the main assumptions underlying any growth accounting analysis and technical efficiency measurement is that all firms in an industry share the same technology and face similar environmental conditions. However, this is not generally the case in reality due to factors such as geography, institutional regulations, market structures etc. that tend to influence the performance measures obtained. There are different factors that can explain the technical efficiency changes taking place across firms. These factors are exogenous variables that include form of ownership, size characteristics, raw materials expenses by firms and government regulations that may be solved only by the frontier approach.

A Two-stage Stochastic Frontier Approach

Exogenous variables have been incorporated into SFA by using a two-stage method. In the first stage, the exogenous factors have a direct influence on the production structure and the technical inefficiency term U is assumed to be independent of these variables, following Coelli and Battese (1992). Thus, the technology is modeled by introducing some representative variables apart from the production factors. Obviously, this approach cannot explain the variations in technical efficiency because the inefficiency item is not directly determined by the exogenous variables. In the second stage approach, these exogenous factors are assumed to affect technical efficiency directly and thus are the determinants of technical efficiency.

To analyze the resource-use efficiency of fertilizer firms, we have used here the parametric stochastic frontier approach (SFA) adopted by Coelli and Battese (1996), which is defined as,

$$Y_{it} = f(x_{it}, \beta, t) \exp(v_{it}) \exp(-u_{it}), \text{ where, } i = 1, 2,..., n \text{ and } t = 1, 2,...,t \qquad (1)$$

Where Y_{it} is the output of i^{th} firm (i = 1, 2,….n) in the t^{th} period (t= 1,2,…t); f(.) is the production frontier; X is a vector of input quantities; t is a time trend index that serves as a proxy for technical change; β is a vector of technological parameter to be estimated.

V_{it} is the statistical error that follows independently and is identically distributed with N (0, $\sigma_v^{2)}$.

Uit's are non-negative random variables associated with the technical inefficiency of production, which are assumed to be independently distributed, such that Uit is obtained by truncation (at zero) of the normal distribution with mean δZit and variance σ^2.

Zit is a vector of explanatory variables associated with the technical inefficiency of production of firms over time; and δ is a vector of unknown coefficients. The explanatory variables in the inefficiency model may include some input variables in the stochastic frontier, provided the inefficiency effects are stochastic.

The technical inefficiency effect, Uit, in the stochastic frontier model (1) could be specified in equation,

$$Uit = zit\ \delta + Wit, \qquad (2)$$

where the random variable, Wit*,* is defined by the truncation of the normal distribution with zero mean and variance, σ^2*,* such that the point of truncation is (-zit δ), i.e., Wit >= (-zit δ).

The method of maximum likelihood is proposed for a simultaneous estimation of the parameters of stochastic frontier and the model for technical inefficiency effects. The likelihood function and its partial derivatives with respect to the parameters of the model are presented in Coelli and Battese (1992) in terms of parameterization of $\sigma^2{}_s$ and γ. Maximum-likelihood estimates of $\sigma^2{}_s$ and γ and μ and η parameters are obtained, using a modification of the computer program, ***FRONTIER 4.1*.** The variance parameters are expressed in terms of, $\sigma^2{}_s = \sigma_v{}^2 + \sigma_u{}^2$ and $\gamma = \sigma_u{}^2 / \sigma^2{}_s$, where the estimate of the total error variance, $\sigma^2{}_s = \sigma_v{}^2 + \sigma_u{}^2$, is labeled sigma 2, and the estimate of the ratio of the standard deviation of the inefficiency component to the standard deviation of the total component, $\gamma = \sigma_u{}^2 / \sigma^2{}_s$, is labeled gamma, and lies between 0 and 1. A value of zero for parameter γ indicates that the deviations from the frontier are entirely due to noise, while a value of one indicates that all deviations are due to technical inefficiency.

The distribution of technical inefficiency effects, U_{it}, is taken to be a non-negative truncation of the normal distribution N(μ, σ2) modeled, following Coelli and Battese (1992) and Greene (1993), to be the product of an exponential function of time as;

$$U_{it} = \eta_t U_i = \exp[-\eta (t- T)] U_i ;\ i= 1,\ldots,n;\ t=1,\ldots,t \qquad (3)$$

Here, the unknown parameter η represents the rate of change in technical inefficiency and the non-negative random variable U_i is the technical inefficiency effect for the i^{th} production unit.

Thus, Technical Efficiency of unit i at time t (TE_{it}), defined as the ratio of the actual output to the potential output determined by the production frontier, can be written as follows,

$$TE_{it} = \exp\{-u_{it}\} = \exp\{-z_{it}\delta - w_{it}\}. \qquad (4)$$

In this way, the differences in the policy regime across time (or across regions) are included in variable z, and efficiency effects are captured. This type of model is referred to as the inefficiency effects model by Coelli and Battese (1996).

Lovell and Sickles (1983) compared the three functional forms for the production frontier: the translog, the generalized Leontief, and the generalized Cobb-Douglas. For our study, the translog frontier production function as a generalization of the Cobb–Douglas production function specified in equation (1) is rewritten in the following form because it is the best fitted model associated with the given data for Indian fertilizer industry.

$$\text{Ln } Y_{it} = \alpha_0 + \beta_L \text{ Ln } L + \beta_K \text{ Ln } K + \beta_E \text{ Ln } E + \beta_M \text{ Ln } M + \alpha_t t + 0.5(\ln L)^2 + 0.5(\ln K)^2 + 0.5(\ln E)^2 + 0.5(\ln M)^2 + \beta_{KL} \text{ Ln } L \text{ Ln } K + \beta_{LE} \text{ Ln } L \text{ Ln } E + \beta_{LM} \text{ Ln } L \text{ Ln } M + \beta_{KE} \text{ Ln } K \text{ Ln } E + \beta_{KM} \text{ Ln } K \text{ Ln } M + \beta_{EM} \text{ Ln } E \text{ Ln } M + (0.5)\, \beta_{tt} t^2 + \beta_{tL} t*\ln L + \beta t_K t*\ln K + \beta t_E t*\ln E + \beta t_M t*\ln M + (v_{it} - u_{it}) \quad (5)$$

Where Y_{it} is the gross value of output for the fertilizer industry; i is for four inputs, namely, labour, capital, energy and materials (L, K, E and M) respectively and i not equal to j. The above specification allows for estimating both technical progress and time varying technical efficiency where the technical inefficiency effects following Majumder (2012) are defined in the later part of the study.
To examine this effect, we have used the panel regression model where inefficiency of firms is taken as the dependent variable while the inefficiency determining factors are considered as independent variables.

Description of Data

The analysis uses data from secondary sources consisting of output (Q) and four inputs (L, K, E and M) and production technology respectively. The CMIE (Centre for Monitoring of Indian Economy) Prowess database provides the financial sources of data for 20 years, from 1993-94 to 2012-13 on 93 fertilizer companies in India. For the various policies announced by the government in respect of the fertilizer sector, the report published by Fertilizer Association of India (FAI) consisting of various issues is considered. To estimate the variables in real terms, each variable is appropriately deflated using the appropriate price index series (RBI wholesale price index as WPI and consumer price index as CPI) at 2004-05 base year prices.

The *value of output* of fertilizer firms has been used to create the index for output. The nominal value of the output has been converted to real values at 2004-05 prices using wholesale price index for fertilizer. For *labour input*, wages and salaries to workers have been taken as a measure. It is deflated by CPI for industrial workers. For *energy input*, fuel consumed data is the proxy that also includes fuel, power, lights and lubricants. This is deflated by the WPI for fuel, power and lubricants given by CSO for getting the real values. *Material expenses* data, which are available, gets deflated by WPI of chemicals products for fertilizer from CSO to get their real values. To construct *capital stock*, we have used gross fixed asset. The standard Perpetual Inventory Method (PIM), suggested by Balakrishnan (2000), is used to construct the capital stock with 1994 as the benchmark. The subsidy data is taken from Ministry of Chemical and Fertilizers, Dept of Fertilizers, GOI, which got deflated by WPI of fertilizer from CSO at 2004-05 base year prices. Here time is taken as a proxy of technology.

Empirical Findings

Factors affecting the efficiency of Indian fertilizer companies

Before explaining the factors affecting the technical efficiency among fertilizer firms, we need to know the trends in technical efficiency over time. For this purpose, the study has used Coelli and Battese (1996) specification of Model 2 that uses the panel data on translog production frontier. The estimated average technical efficiency score that is directly given by Frontier 4.1 technique is presented in table 1 below.

Table 1: Average Technical Efficiency Score (in percent terms) for Fertilizer Companies

Year	Average Technical Efficiency Score (percent)
1994	70
1995	69
1996	68
1997	66
1998	65
1999	64
2000	62
2001	61
2002	59
2003	58
2004	56
2005	55
2006	53
2007	52
2008	50
2009	48
2010	47
2011	45
2012	44
2013	42
Average (1994-2013)	**57**

Source: CMIE Prowess.

For 93 fertilizer companies, the average technical efficiency is 0.57 over twenty years, which implies that companies are operating at 57 percent of their potential maximum output determined by frontier technology and hence, have a lot of potential to improve. The possible reasons for such inefficiency may include the poor infrastructure of the receiving Indian fertilizer companies, very limited R & D activities of the recipient companies, and last but not least, inadequate technology support services. All these seem to have contributed to the condition of this sector. These are some of the factors that may have caused inefficiency among the Indian fertilizer firms, according to a paper by Schumachar (1998). Although he didn't deal with the Indian fertilizer industry in particular, the study referred to comparable economies.

Now, let me discuss the factors affecting the technical inefficiency of fertilizer firms.

Factors Affecting the Efficiency of Indian Fertilizer Companies

To explain the variation in the efficiency scores for firms, we selected a number of explanatory variables, following Majumdar (2012) and Sharma (2009). The explanatory variables can be broadly classified into three groups: Firm's Structural Variables, Firm's Strategy Variables and Policy-related Variables. To explain this, the estimated technical inefficiency scores are used as a dependent variable while the explanatory variables are discussed in the next section.

Firm's Structural Variables: The structure of a firm is determined largely by its size, ownership, age, and technology. We took each of these factors into consideration.

Size of the firms

The size of a firm is one of the most important factors in measuring the efficiency of firms. Larger firms generally enjoy higher efficiencies compared to small ones from a business perspective. This also can result in better performance by larger firms relative to the smaller ones, according to Penrose (1959). On the other hand, Downs (1976) found the larger size making the task difficult for managers due to the need for increased coordination.

Our single data source for the entire analysis/paper happens to be the CMIE Prowess report. Hence, we had to come up with our own definition of large and small firms, based on the fixed asset value of firms, as of the financial year 1990. Firms with a fixed asset value of less than 50th percentile were defined as small firms and the rest as large firms. Detailed technical efficiency scores by large and small firm types are provided below in table 2.

Table 2: Technical Efficiency Score (per cent) from the Perspective of the Size of Fertilizer Firms

Year	Large sized firms	Small sized firms
1994	72	69
1995	70	67
1996	69	66
1997	68	64
1998	66	63
1999	65	61
2000	64	60
2001	63	58
2002	61	56
2003	60	55
2004	58	53
2005	57	51
2006	56	49
2007	55	48
2008	53	46
2009	52	45
2010	49	44
2011	47	42
2012	46	40
2013	44	39
Average (1994-2013)	**59**	**54**

Note: Firms with a fixed asset value of less than Rs. 15 crore were defined as small sized firms; and firms with a fixed asset value equal to or more than Rs 110 crore as large firms (based on the value of fixed asset volume data for 2000).

Source: CMIE Prowess.

It seems that larger fertilizer firms have achieved higher technical efficiency than small firms.

Ownership Pattern

We also distinguish the structure of firms based on ownership pattern. The Indian fertilizer market consists of a few different ownership patterns, namely, public, private and cooperative. In our study, we have used the information on sales as the key variable (from CMIE PROWESS database) for analyzing the ownership pattern of this industry. The average technical efficiency score by ownership type is provided in table 3 below.

Table 3: Average Technical Efficiency score (percent) from the perspective of Ownership for the Fertilizer firms:

Year	Public sector	Private sector	Cooperative sector
1994	67	71	71
1995	65	69	70
1996	64	68	69
1997	62	67	68
1998	61	66	66
1999	59	64	65
2000	58	63	64
2001	56	61	62
2002	55	60	61
2003	53	59	59
2004	52	57	58
2005	50	56	56
2006	48	54	55
2007	46	52	53
2008	45	51	51
2009	43	49	50
2010	41	48	46
2011	40	46	40
2012	38	45	37
2013	36	43	32
Average (1994-2013)	**52**	**58**	**56**

Source: CMIE Prowess.

The most efficient public sector fertilizer firms are Brahmaputra Valley Fertilizer Corporation, Madras Fertilizer Corporation Limited etc. while the least efficient are Hindustan Agro Chemicals, Rashtriya Chemicals & Fertilizers etc. The most efficient private sector fertilizer firms include Chambal Fertilizers & Chemicals, Coromandel International Limited etc. and the least efficient are Agro Chemical Punjab, Indo Gulf Corporation etc. Here, as Table 3 shows, the private sector fertilizer firms seem to have scored higher, on an average, in respect of technical efficiency than public sector undertakings.

Age of the firms

Another important factor is the age of firms. Following economic theory, the relationship between a firm's age and its performance is ambiguous in nature. In this study, we have calculated a fertilizer firm's age in a particular period by taking the difference between the particular periods and the firm's incorporation year. The following Table 3 shows the age of fertilizer firms (divided into nine time spans), based on the incorporation year of firms with respect to 2013. Depending on this classification, among 93 fertilizer firms in our study, Udaipur Phosphates & Fertilizers is an old fertilizer firm in India, which is technically inefficient, while Pyrites Phosphates & Chemical is a young one, which is technically efficient. This may be due to the lack of technological advancement among the old firms. The old fertilizer firms

are less efficient in terms of adopting modern technology in their production process as compared to the new ones. Details of the technical efficiency by age are provided in table 4 below.

Table 4: Average Technical Efficiency Distribution (In percent) According to Firm's Age

Age	1994-1997	1998-2001	2002-2005	2006-2009	2010-2013	Average
1-5	69	64	58	52	45	**58**
6-10	68	63	57	51	44	**57**
11-15	64	59	53	46	39	**52**
16-20	68	62	56	50	43	**56**
21-25	69	64	58	51	46	**58**
26-30	68	63	57	51	45	**57**
31-35	68	62	56	50	44	**56**
36-40	75	71	66	61	55	**66**
41 and above	61	55	48	41	34	**48**

Source: Author's compilation using CMIE Prowess database

From the above Table, it can be observed that some of the most efficient firms are the younger firms aged one to five years (4 percent of the total firms). For the study period, the minimum and maximum average TEs for young firms within 1-5 age groups work out to 45 percent and 69 percent respectively while for firms aged between 6 to 10 years, it is just behind the young firms (57 percent). The minimum average TE for any firm in this group amounts to 44 percent, but given their potential, they may achieve as high as 68 percent. TE for the older firms (40+ years) is found to be as low as 48 percent on an average. Interestingly, 36-month to 40-month-old firms seem to be the most efficient (3+ years). Probably firms reach their peak in terms of effective usage of new technology during this phase.

Energy-Capital ratio (EK)

Energy saving technology, which improves energy-use efficiency, has the potential to become a capital intensive process. Efficient utilization of energy is one of the important goals set for the fertilizer sector. Conversion from a non-gas based fertilizer unit to a gas based one is a way of experimenting with a new strategy that depends more on capital investment. However, empirical literature shows an ambiguous relationship between capital and energy. In some cases, capital and energy act as substitutes, whereas they are complementary to each other in some other cases. So, we have included energy-capital ratio EK as an independent variable here which could have either a positive or negative coefficient. However, this raises a question regarding the usefulness of capital in the efficiency allocation of energy resource strategy by the Indian fertilizer companies, going by the trend in recent years.

Firm Specific Strategy Variables

The important strategy variables considered in our model are R&D intensity, Marketing expenses intensity, Environmental expense intensity, Export intensity and Import intensity.

Research and Development Intensity (R&D)

R&D intensity is measured in terms of the ratio of a given firm's R&D expenditure on lag of pre one year (t-1), pre two years (t-2) and pre three years (t-3) to the total value of sales for that particular year (t) respectively. It is supposed to favourably affect the efficiency factor, according to Ornaghi (2006). This is because firms involved in R&D can invent a superior process technology based on which they can earn higher revenue while employing the same level of inputs. This theory was propagated by Aghion (1992). However, as per Helpman (1992), heavy allocation of resources to R&D can also reduce efficiency if firms fail to get the expected return on R&D. Also, firms with a longer span in production from their date of incorporation (experienced firms) could incur relatively more expenditure on R & D as compared to younger firms, and as a result, are more likely to experience higher input use efficiency.

A number of fertilizer producers have full-fledged R&D centers like Gujarat State Fertilizer Corporation, Baroda, The Fertilizer and Chemicals Travancore, Cochin, Southern Petrochemical Industries Corporation Ltd., Tuticorin, Gujarat Narmada Valley Fertilizers & Chemicals Ltd., Bharuch etc. Most of the R&D centres with fertilizer companies have been recognized by the Department of Scientific and Industrial Research (DSIR). The R & D expenditure by Indian fertilizer firms from 2004 onwards and the R & D's share in the total expenses, on an average, work out to more as compared to non R & D expenses.

Marketing Expenses intensity

In CMIE Prowess, Marketing expenses include commissions, rebates, discounts, marketing sales, promotional expenses on direct selling agents & entertainment expenses, packaging and packing expenses. Since fertilizer industry is related more to the packaging of its products, it's measured in terms of the ratio of a firm's marketing expenses incurred per unit of its sales and hence, it is taken as an indicator of a firm's efficiency. It also captures a firm's allocation for sales and marketing efforts. Higher allocation for marketing expenditure may indicate an effort to strengthen the fertilizer firm's brand and product image, which may lead to higher revenue and in turn enhance output efficiency.

Environmental Expenses intensity

Under the miscellaneous expenditure in CMIE, environment/pollution control related expenses are included. During the past 10 years or so, the topic of global warming has been gathering steam. An increased focus on energy issues during the last few years has already caused a positive downward trend in both energy consumption and gas emissions. This has been made possible due to the ongoing replacement of old technology and incorporation of energy conservation measures. More consciousness of environmental policies plays a significant role in controlling pollution levels and promoting increased efficiencies through energy saving techniques.

International performance is also an indicator for measuring a firm's efficiency. But studies indicate that there is a gap between exports and imports in the Indian fertilizer sector.

Export intensity

Productivity growth helps the industrial sector in achieving an international standard of competitiveness in a globalized world. Increased exports lead to increased competition among firms. More importantly, increased competition may provide further scope for specialization that, in turn, may further improve a firm's efficiency. The fertilizer sector in India serves the indigenous sector more than international needs. India exports its fertilizer products mainly to Nepal and Oman.

Import intensity

Import of raw materials may also influence a firm's efficiency. More import of high quality raw material may improve its production efficiency. The department of fertilizer has always tried to maintain the required fertilizer stock for farmers through timely import of fertilizers and raw materials such as urea, ammonia, phosphoric acid, diammonium phosphate (DAP) and muriate of potash (MOP). Over the past few years, the dependence on imports for the supply of urea, and phosphatic fertilizers has increased as domestic production has not been sufficient to meet the growing demand.

Policy Related Variable in the Form of Regulation Dummy (Policy Dummy)

The fertilizer industry will continue to operate under a regulatory regime even after the switch-over of naphtha and fuel oil based plants to natural gas as feedstock for achieving higher energy efficiency. Also, investment in medium and large size energy conservation schemes usually involves a long payback period. Finally, here, we have added the dummy variable to test whether Energy Saving Act, 2004 has brought about any significant change in energy use efficiency among the Indian fertilizer companies. A time dummy is introduced taking the value 1 from 2004 onwards and 0 for the rest of the years as part of examining the impact of policy reform on the efficiency of firms.

The following functional relationship between efficiency level and its various determinants is considered for this study and we have used a panel regression model.

$$(IE)_{it} = \infty + \beta_1 Age + \beta_2 Size + \beta_3 Ownership + \beta_4 K/E + \beta_5 R\&D\ Exp\ (t-1)/Sales + \beta_6 R\&D\ Exp\ (t-2)/Sales + \beta_7 R\&D\ Exp\ (t-3)/Sales + \beta_8 Marketing\ Exp/Sales + \beta_9 Environmental\ Exp/Sales + \beta_{10} Export/Sales + \beta_{11} Import/Sales + \beta_{12} Policy\ Dummy + _{it} \quad (6)$$

A summary of descriptive statistics is shown in table 5.

Table 5: Summary of Descriptive Statistics for Inefficiency Variables in Case Indian Fertilizer Firms from 1993-94 to 2012-13 (2004-05=100 (base year)

Variable	Description	Mean	Std. Dev.	Min	Max
Age	Firm's age for a particular period by taking the difference between that period and the firm's incorporation year.	3.19	0.72	1.10	3.99
Size	Total fixed assets by firms	8.92	3.70	0.00	12.47
Ownership pattern	(Private=1)	0.50	0.50	0.00	1.00
Capital /Energy ratio	Capital per unit of energy	-0.41	1.26	-5.35	2.25
R_D (t-1) per Output t	Ratio of the firm's expenditure on R & D with one year lag.	0.26	2.07	0.00	16.80
R_D (t-2) per Output t	Ratio of the firm's expenditure on R & D at 2 years lag	0.00	0.00	0.00	0.01
R_D (t-3) per Output t	Ratio of the firm's expenditure on R & D with 3 years lag	0.00	0.07	0.00	0.03
Market exp per output	Commissions, rebates, marketing sales, promotional expenses on DSAs & entertainment expenses, packaging expenses	0.45	3.62	0.00	29.40
Env. exp per output	Environment/pollution control related expenses	0.45	3.62	0.00	29.40
Export intensity	Export per unit of Output	0.12	0.59	0.00	3.31
Import intensity	Import per unit of Output	0.01	0.02	0.00	0.14
Policy	Dummy	0.08	0.12	0.00	0.52

Note: All values are in Rs. Cr. and total number of observations is 1860. All variables are transformed into logarithmic form before they are used in actual estimation.

Source: CMIE Prowess

A panel regression model is specified below for hypothesizing a functional relationship between inefficiency effects and its various determinants as mentioned above. Results of the panel regression model are provided in Table 6.

Table 6: Panel Regression Results with Respect to Inefficiency Determining Factors

Variables	Coefficient	T	P>|t|>0
Constant	0.606	2.17**	0.03
Age	0.092	1.60***	0.10
Size	-0.243	-4.14*	0
KE	0.056	3.51*	0
Ownership	0.015	1.17**	0.04
R & D Intensity=R & D Exp (t-1)/Sales	0	-0.37	0.36
R & D Intensity=R & D Exp (t-2)/Sales	-0.0001	-0.63	0.54
R & D Intensity=R & D Exp (t-3)/Sales	-0.0007	-0.88**	0.08
Marketing Intensity= Markt Exp/Sales	-0.001	-1.33***	0.1
Environmental Intensity= Env Exp/Sales	-0.002	-0.27	0.78
Export Intensity = Export/Sales	0.001	0.14	0.88
Import Intensity = Import/Sales	-0.001	-0.98**	0.02
Policy dummy	0.052	0.51	0.61

Source: Compiled by Author using CMIE Prowess database

Notes: The dependent variable for frontier estimation is Inefficiency Effects $(IE)_{it}$ and * indicates the 1 percent level of significance, **Significant at 5 per cent level and ***significant at 10 per cent level.

Number of observations: 930, Wald chi = 224.97

Log likelihood = 662.79 ,

Breusch-Pagan test for heteroskedasticity

Ho: Constant variance

chi2(1) = 0.47,

Table 6 summarizes the main findings based on the panel data model for output efficiency of firms. It can be observed that the estimated model is highly significant, as suggested by high values of Wald–Chi square statistics. This implies that the explanatory variables together explain the significant variations in the efficiency levels of firms. The Breusch-Pagan test for heteroscedasticity accepts the null hypothesis, which is the acceptance of a constant variance within the model. Our observations based on the above analysis are discussed below.

A firm's age is found to be significantly affecting its efficiency obtained from the model. For the Indian fertilizer industry, age is positively related to the firm's efficiency. This implies that the old and more experienced firms are more technically efficient because of their production-related experience, as compared to the younger ones.

Figures presented in the table also suggest that privately owned fertilizer firms operating in India are more efficient than publicly owned companies. It also becomes clear from the literature that private fertilizer companies are increasingly taking interest in this sector while the volume of sale of the public sector fertilizer firms in terms of share has declined over the years.

A firm's size is significant for its efficiency level in the fertilizer sector. But the coefficient is negative in value. This implies that with an increase in the size of a firm, the efficiency of the firm decreases or stated otherwise, there is an increase in its inefficiency level. This implies that a large sized

fertilizer firm tends to become less technically efficient relative to its nimble and small sized counterparts/firms.

The KE ratio is significantly and positively associated with a fertilizer firm's efficiency level. If the spend on energy is decreasing after attaining a certain threshold level of energy efficiency, assuming constant capital, then KE ratio increases, resulting in an increase in the firm's efficiency. The strategy of improving the energy-use efficiency of the fertilizer sector may lead to a capital intensive process and in that case, a higher capital-energy ratio will be associated with a higher level of efficiency.

We have found that in spite of the growing importance of R&D for the pre first and second years, as (t-1) and (t-2), the variable is found statistically insignificant in explaining the efficiency levels of fertilizer firms, while for pre third years (t-3), it is found statistically significant, thereby pointing to a negative impact on the efficiency levels of fertilizer firms. This could be due to the fact that R&D relatively is a recent phenomenon for most of the fertilizer companies and therefore, firms may take some time before fully realizing the potential benefits associated with R&D.

The marketing cost of fertilizers as well as packaging and storage became negative and significant with respect to efficiency. This is more for non-consumable fertilizer products that are far from their consumers' interest. So, there is less scope of making it into a consumer brand. Also, lack of proper infrastructure facilities is mainly responsible for the increase in the marketing costs of fertilizers. Thus, an increase in the high cost of packing and packaging materials and services like transport, handling and storage could be a major cause underlying the inefficiency of fertilizer firms.

Basically, the Indian fertilizer market is import oriented. Exports do not count much here. This is reflected by the coefficient results of export and import intensities. From table 6, it is evident that import becomes significant with efficiency. Recently, India is showing interest in importing urea. This could not only minimize the demand-supply gap, but also help to reduce the subsidy burden borne by the government (assuming domestic demand of urea remains constant) through cheaper urea imports. Moreover, in our study, a negative relation of import intensity with efficiency implies a low quality of imported products in the fertilizer markets that may lead to more inefficient production. Low quality in imported products makes fertilizer firms more inefficient. Thus, quality checks are unavoidable with respect to the sale of fertilizers in India. As per the Fertilizer Control Order (FCO) norms, manufacturers/importers can sell their fertilizers to farmers only after they meet the standard of quality mentioned in the FCO order. State Governments control the quality of fertilizers supplied by the manufacturers/importers as prescribed under the FCO. For checking quality and issuing certificates, there are about 74 fertilizer testing laboratories in the country.

Concluding Remarks

In this study, we have estimated the SFA and output-oriented technical efficiency of Indian fertilizer firms. It also measured technical inefficiency as a function of various firm specific controllable factors. From the empirical analysis, it is observed that the average technical efficiency of firms is 0.57 over the study period. This study also finds that TE decreases over time, but very slightly.

A look at the determinants of efficiency levels of firms indicates that large and experienced firms are more efficient than small and new firms. A possible route for the small as well as the medium sized firms to gain efficiency is to merge and grow in size. The study also indicates that the private sector fertilizer firms are more efficient than public sector undertakings. Hence, these firms can enter into technological collaborations with private firms in order to gain more efficiency. A large number of technological collaborations noticed in the sector in recent times are a welcome move. Also, many public fertilizer plants have been merged with private companies to overcome their inefficiencies.

More importantly, the study indicates that adopting capital-intensive techniques or importing technology by itself may not improve the output efficiency of firms. We have found that in spite of the growing importance of R&D, its impact in the post three years (t-3) is statistically significant in a negative way with the efficiency levels of fertilizer firms. This could be due to the fact that R&D is a recent phenomenon for most of the fertilizer companies. It takes some time to realize the benefits of new technology. Thus, a firm's performance may drop in the short run if the success from R&D is not immediate. Moreover, by importing raw materials, firms may improve their efficiency. But in the fertilizer sector, the use of imported materials may not improve technical efficiency. This may create issues regarding quality. Moreover, it is well known that fertilizer firms do not spend heavily on marketing activities. We have found that spending more on promotional activities does negatively affect the technical efficiency of firms in general.

The fertilizer industry of India is presently going through a phase of huge transition because of the various policy changes introduced by the Government. We may understand the nature of the fertilizer sector in India based on the various factors we have discussed here relating to the efficiency of fertilizer firms.

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