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An Evaluation of Input-specific Technical Efficiency of Indian Fertilizer Firms

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AN EVALUATION OF INPUT-SPECIFIC TECHNICAL EFFICIENCY OF INDIAN FERTILIZER FIRMS

Soumita Khan[*]

Abstract

This paper examines the competitiveness of Indian fertilizer firms by computing their input-specific technical efficiency from 1993-94 to 2012-13, using stochastic frontier approach. Analysis of input efficiency is important as it provides us with insights into output efficiency. Tracking economy-wide input efficiency performance has recently received increasing attention in manufacturing industries. The main point to be noted is that energy- specific technical inefficiency plays a major role in inter-firm efficiency differences of the fertilizer sector. Also, measures of input- specific technical efficiency may be useful for policy purposes. From our present study on fertilizer sector, the production planners will have tools to set targets of different inputs to produce a given level of output and can take a measure aiming to reduce technical inefficiency of a specific input. Another highlighting issue from of this study is that the relation between the size of the fertilizer firm and their consumption per unit of energy in case of fertilizer sector is not effective too much. That means size is always not a significant factor for a firm's energy efficiency measurement.

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

JEL Classifications: D21, D22, Q20, L660.

Introduction

One of the objectives of the reform process initiated for the Indian fertilizer industry is to remove the hurdles of regulation and allow firms to function freely in response to market forces. To fulfill this objective the Indian Government pursued certain policies, like removing the restrictions on the export of fertilizer products, limiting the scope of price control of fertilizer components etc. Such policies were implemented with the expectation that the liberalized market environment would allow fertilizer firms to function freely, enter into technological collaboration with foreign firms, introduce new products and processes thereby achieving higher efficiency and productivity. However, such competitive environment may not benefit all firms equally. In an industry where firms differ with respect to their access to technology and state-of-knowledge, the process of liberalization may create gainers and losers. In other words, a performance differential may arise between firms. In this regard, analyzing the efficiency of the firms is important to study. This paper is primarily devoted to such an investigation. In efficiency analysis, it is assumed that when all firms operate in a similar environment, they may not be able to carry out their objectives in most optimal manner even. Most efficient firms for a particular industry are operating on the frontier which is the envelope. For example, in fertilizer industry, with 93 firms in this

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study, there may be a small set of firms who are the most efficient. Researchers are interested in finding out that combination of inputs used by these firms and resulting output, which makes them the most efficient within the 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 actual production by any particular firm from the frontier, which indicates the level of inefficiency potentially faced by this firm.

In efficiency related literature, there are two ways of measuring the technical efficiency of the firms, namely, the output-specific technical efficiency that captures how far an inefficient firm can scale up its output to reach the frontier with the level of inputs it incorporates; and the input-specific technical efficiency that identifies how far a firm can reduce its input usage for a given level of output it produces. Due to the presence of returns to scale, technical efficiency may not be equal, both from input and output side. Most of the previous studies, especially Lovell (1983), have either given priority to the output expansion of firms to compute their output efficiency or have computed the input efficiency by minimizing its level of input usages. In all these studies, technical efficiency is defined as the ability and willingness of any producing unit to obtain the maximum possible potential output from a given set of inputs and technology. It is generally assumed that the potential output is obtained by following the best practice methods, given the technology. This implies, in turn, that the potential output is determined by the underlying production frontier, given the level of inputs.

However, a profit maximizing firm strives to reduce its input usage and increase its output production at the same time. In the light of the study, Khan S (2017), it could be concluded that the Indian fertilizer sector may be inefficient from output perspective. Thus, it may be necessary to find out significance of inputs used for production in this sector which may also indicate contribution of a particular input in output inefficiency. For this we have attempted to measure the input-specific efficiencies for the Indian fertilizer firms. There has been a growing interest in developing an appropriate measurement for monitoring and comparing the input-specific efficiency performance among the fertilizer firms. The econometric approach is more flexible considering the technical efficiency of firms. Therefore, this paper will focus on input-specific efficiency measurement at a firm-level and propose a parametric frontier approach to estimate the economy-wide input efficiency performance in case of Indian fertilizer sector.

This paper unfolds in the following manner. In addressing the earlier issue, some existing reviews are looked upon in the next section on general empirical studies related to the input specific efficiency measurement for manufacturing firms. After the review of literature section, this study is finding out an economic-wide input-specific efficiency index considering the *Stochastic Random Coefficient Model* over 93 fertilizer companies for 20 years as the methodology. Data sources used for an empirical exercise are presented in the next section. Finally, empirical results are presented, followed by conclusions.

Empirical Reviews on Technical Efficiency Measurement of the Indian Manufacturing Sector

In this connection we mention in brief some of the studies that have been carried out to examine the technical efficiency for various industries in India. Some of the notable studies that have used the parametric frontier approach to efficiency analysis are by Neogi and Ghosh (1994), Krishna and Mitra (1998), Kalirajan and Bhide (2005), Jayadevan (1996), Trivedi (2003), Srivastava (2000) and others. Using a time-varying frontier production approach, Neogi and Ghosh (1994) estimated the inter-temporal movement of the technical efficiency of the manufacturing firms. The study indicated that there has been a fall in the efficiency of the firms due to globalization. An inquiry into the sources of inter-industry efficiency variations shows that skill, labour productivity and profit play significantly positive roles, while capital intensity works against general beliefs. The firm-level panel data of some selected manufacturing industry was also employed by Krishna and Mitra (1998) to examine the productivity and efficiency- related issues. The study could not find a strong evidence of the productivity or efficiency effect of the reform. Srivastava (2000) examined the efficiency of the manufacturing firms for the periods between 1980-81 and 1996-97. He found that the technical efficiency of the Indian manufacturing firms had gone down in the post-liberalization era. The study by Kalirajan and Bhide (2005) was the first of its kind to use the random coefficient model developed by Swamy (1971) and Swamy and Mehta (1977), to estimate the frontier production function and the efficiency of the Indian manufacturing sector. The study indicates that due to liberalization, the productivity growth of the manufacturing sector has slowed down which is mainly due to a fall in the technical efficiency of the firms. The impact of liberalization, FDI flow and spillover on the efficiency gain of the Indian manufacturing firms were studied by Kathuria (2002) and also by Siddharthan (2004) using the stochastic frontier approach.

A number of studies have also employed the non-parametric Data Envelopment Analysis (DEA) approach to examine the efficiency and productivity of the Indian manufacturing sector. Using the firm level data and employing the non -parametric technique of DEA to estimate the efficiency of the firms, study by Ray (2002) indicates that the average efficiency of the Indian manufacturing sector had declined between 1991 and 1996. There was however, some improvement in the efficiency after 1996. The study also indicates that firms with foreign ownership or Multi-National Enterprises are significant in explaining efficiency. The non-parametric approach has also been employed to examine the dynamics of efficiency for the Indian manufacturing sector located in different states by Mukherjee and Ray (2004). Utilizing the concept of super-efficiency, this study indicated that there was no change in the ranking of the firms in the post reform period. Also, no evidence of convergence in the efficiency of the firms was noticed in the post reform period. The impact of the ownership pattern, particularly the public and private ownership, on the efficiency was also studied by Rammohan (2007) for eight different sectors, namely chemical, electronics, steel, mineral, non-electrical, service, textile and transport, by constructing separate frontiers for each sector. The study indicated that only for chemical, iron and steel and textile industry the private sector's technical efficiency scores were superior; for electronics and services, the public sector's scores are superior and for minerals, non-electrical machinery and transport - there was no difference between the private and public ownership patterns.

As we can make out from the above review, there are ample numbers of studies examining the efficiency of the manufacturing sector at the inter-industry level. Siddharthan (2004) had tried to find the impact of policy changes that however cannot be assessed adequately by doing an inter-industry study, because these studies assume that firms in an industry behave alike and therefore the industry level characteristics can be attributed to all firms in an industry. With free market, new firms can enter the market with advanced technology. Further, the existing firms can also develop new strategies to cope with the changing scenario.

A common practice to derive economy-wide input efficiency indicators is to aggregate the effects of input specific intensity changes at input end-use or sub-sector level to give a composite input efficiency performance index. A study of Ang BW (2000 & 2006) stated that index decomposition analysis (IDA) technique is the basis of this practice, which can be used to decompose a change in input consumption over time in a sector into several pre-defined effects including the input intensity effects. This IDA-based approach has been adopted by a number of countries including Canada, New Zealand and the United States to track their economy-wide energy efficiency trends over time. Other than IDA-based energy efficiency studies, many researchers have also applied data envelopment analysis (DEA) approach to comparing the energy efficiency performance of different countries/ regions from the viewpoint of production efficiency. Despite its strengths, DEA is a nonparametric mathematical programming approach that does not consider statistical noises. Thus, the parametric frontier approaches with noise variable has measuring energy efficiency performance at economy-wide level considering the stochastic frontier analysis (SFA) technique. Based on the DEA, one of an important study by Majumdar (2014) had measured the input-specific technical efficiency in case of Indian Pharmaceutical industry. This study examines the productivity changes and its various components like efficiency, technical and the production possibility ratio (PPR) change on R&D related activity. Moreover, concerning the determinants of best practice methods, two alternative models have been developed by Kalirajan and Obwona (1994a) which are referred to as neutral and non-neutral frontier models. The former assumes that technical efficiency is independent of the levels of input used but is dependent on the method of application of inputs. In contrast, the non-neutral frontier model assumes that both the methods of application of inputs as well as the level of inputs (i.e., scale of operation) determine the potential output and thus, the estimated frontier is modeled as a non-neutral shift of the traditional average production function. The approaches that have been used to model non-neutral production was developed by Kalirajan and Obwona (1994a) with the Stochastic Varying Coefficient Frontier (SVCF) model that related the notion of the non-neutral frontier with cross-sectional and possibly temporal variation in production response coefficients which include not only the intercept term as in the traditional frontier framework but also the slope coefficients. The idea of slope-varying coefficients is consistent with the methods of application of inputs to depend on the level of inputs.

Concentrating on the Indian fertilizer sector, we found that most of the works were based on the traditional growth accounting approach. The relevant efficiency-related questions have not been adequately addressed for the fertilizer sector in India. Depending on these gaps, the present study is more concentrated on the measurement of input-specific efficiency of Indian fertilizer firms. The next section deals with the methodology adopted, data sources and analysis related to the study.

Methodology of Measuring the Input-Specific Technical Efficiency from the Stochastic Random Coefficient Frontier (SRCF) Model

Measurement of efficiency of manufacturing industries serves two important purposes. It helps to benchmark the relative efficiency of an individual firm against the 'best practice' firms and secondly, it helps to evaluate the impact of various policy measures on the efficiency of this sector.

Assume that there is a sample of firms whose economy-wide input efficiency performance is to be compared. Consider the neo-classical one-sector aggregate production framework in which capital (K), labor (L), energy (E) and materials (M) are treated as inputs and gross domestic product (Y) is taken as the output.

Conceptually, the production technology can be described as follows:

$$T = \{(K, L, E, M, Y): (K, L, E, M) \text{ can produce } Y\} \quad (1)$$

T consists of all the feasible input–output vectors and is often referred to as the production technology, which can also be represented by its equivalent input set or output set. In production theory, T is often assumed to be a closed and bounded set.

Let us now suppose that the production technology of firms is expressed as a Cobb-Douglas production function, such as:

$$\text{Ln } (Y_i) = \beta_{oi} + \Sigma\beta_{ik} \ln (x_{ik}) + {}_{I} \quad (2)$$

Where,

Y_i = the output of the i^{th} firm

X_i = A vector conditioning factor that affects production.

βi = a K vector of unknown parameter for each unit i.

εi = Assumed to be independent and identically distributed as N (0, σ2)

We use the Swamy (1971) random coefficient approach which assumes that each fertilizer firm's parameter vector β_i varies from the mean response by a vector of random errors μ_i that is:

$$\beta_{ik} = \beta_k + \mu_i \quad (3)$$

Substituting 3 on 2 gives:

$$\text{Ln } (Y_i) = \beta_o + \mu_{i0} + \Sigma (\beta_k + \mu_{ik}) \ln (x_{ik}) + {}_{I} \quad (4)$$

$$\text{Ln } (Y_i) = \beta_o + \Sigma \beta_k \ln (x_{ik}) + \mu_{i0} + \Sigma \mu_{ik} \ln (x_{ik})) + {}_{i} \quad (5)$$

$$\text{Ln } (Y_i) = \beta_o + \Sigma \beta_k \ln (x_{ik}) + w_i \quad (6)$$

Where, $w_i = X_i \mu_i + {}_{i}$

Now we obtain the feasible GLS estimator of β.

Having equation (6), Kalirajan and Obwona (1994b) followed the tradition of the frontier literature and measured output-specific technical efficiency by the ratio of actual to potential output, i.e.,

TE =Y/Y*. However, in calculating the potential output that serves as a benchmark they used the maximum of the estimated values of the response coefficients for each input which are defined as:

$$\beta_{ik} = \text{Max} \{ \beta_k + \mu_{ik} \} , i = 1\ldots n; k= 0,1,\ldots..K \quad (7)$$

Then, the frontier is given as:

$$\text{Ln} (Yi) = \beta_{ik} + \Sigma \beta_{ik} \ln (xik) \quad (8)$$

There are two equally possible roots for the origin of the maximum response coefficients. On the one hand, it may be argued that not every firm would be applying all the inputs efficiently and thus, the maximum response coefficients need not come from a single firm. The main reason for this is that best practice methods vary from input to input. On the other hand, we may argue that a firm which uses some inputs efficiently may also use all inputs efficiently and thus the possibility that all maximum response coefficients may come from the same firm cannot be completely ruled out.

In a stochastic frontier model, it is quite likely that none of the firms in the sample operates with full efficiency but this is due to stochastic disturbances and not because the frontier is not feasible to sample participants. Second, the resulting frontier may not be well defined in the sense that it violates certain theoretical properties Kalirajan and Obwona (1994a), Kalirajan and Obwona (1994b), Kalirajan and Huang (2001) study in particular estimates the potential and actual output for each firm separately from different firms.

A different procedure for calculating technical efficiency scores is proposed in this study to resolve the above shortcomings of the SRCF model which relies on the idea that best practice methods refer to the whole set of inputs used by a firm instead of each input separately. Starting with the basic relation that

$Y_i = f (.) TE_i$, where f (.) refers to the production frontier, we can rewrite it for the Cobb-Douglass form as:

$$\text{Ln} (Yi) = \beta_0 + \Sigma \beta_k \ln (xik) + \ln TE_i \quad (9)$$

On the other hand, by explicitly considering the random coefficient formulation of Eq. 4, it may be written as,

$$\text{Ln} (Y_i) = \beta_o + \Sigma \beta_k \ln (x_{ik}) + \mu_{i0} + \Sigma \mu_{ik} \ln (x_{ik}) \quad (10)$$

Then by comparing Eq. (10) and (9) yields:

$$\ln TE_i = \mu_{i0} + \Sigma \mu_{ik} \ln (x_{ik}) \quad (11)$$

Notice that Eq. (11) is completely analogous to the measure of technical efficiency used by Huang and Liu (1994) in the maximum likelihood formulation of the non-neutral frontier model. Given the assumptions about μ, it is clear that the expected value of $\ln TE_i$ in eq (11) is equal to zero implying that the expected value of TE_i is equal to one.

On the other hand, Kalirajan and Obwona (1994a) and (1994b) both respectively used the ratio of the actual to the maximum response coefficients for each input to obtain firm- specific estimates of input- specific technical efficiency. That is:

$$ITE^k_i = \beta_{ik} / \text{Max} \{\beta_{ik} \} \quad (12)$$

Where values <1 indicate inefficiency.

Also the notion of ITE^k_i may be used to identify in a theoretically consistent way the technical efficient use of individual inputs. In particular, Kopp (1981)'s measure of ITE^k_i is defined as the ratio of minimum feasible to observed use of each input conditional on the production technology and the observed levels of output and other inputs. Using this expression we can calculate the input-specific technical efficiency of the Indian fertilizer firms.

Data Sources

The present study analyzes the input-specific efficiency of Indian fertilizer sector. In analyzing input efficiency, we have used the parametric frontier technique for 93 fertilizer companies of 20 years. The main data source is PROWESS from Center for Monitoring Indian Economy (CMIE). The study considers one output (Y) and four inputs; Labour, Capital, Energy and Materials, Production Technology. The total sale of the firms has been taken as the value of total output (Y). Labour (L) is measured in terms of wages and salaries for the workers. Capital (K) is the book value for plant and machinery and building. Material inputs (M) are measured in terms of the expenditure of 93 fertilizer firms as raw material. Lastly, energy input (E) is measured in terms of the expenditure for power and fuel. Also, time is taken as a proxy of technology here. To bring the variables in real terms, each variable was appropriately deflated.

Analysis of the Study

Measuring Input-specific Efficiency of Indian Fertilizer firms

In our empirical analysis, the Stochastic Random Coefficient model by Kalirajan (1994a and 1994b) has been applied to study the economy-wide input-specific efficiency performance of 93 Indian fertilizer companies over 20 years. We first estimate the input efficiency based on labour, capital, energy and material. This is calculated by measuring the distance between optimum usage point and actual usage point. Here, since a single output and four inputs model has been used, the efficiency scores are available for output and all four inputs, namely, energy, raw materials, capital and labour. Table 1 provides the average input-specific efficiency score for 93 fertilizer companies over 20 years by using ***Stata SE 10 Package.***

Table 1: Measuring Input-specific Technical Efficiency Score using the Parametric Stochastic Random Coefficient Frontier Model from 1994 to 2013 (base year 2004-05= 100)

Firms	Labour Efficiency	Capital Efficiency	Energy Efficiency	Material Efficiency
A P T Packaging Ltd.	0.797	0.872	0.334	0.568
Adarsh Chemicals & Fertilisers Ltd.	0.749	0.86	0.256	0.843
Agro Chem Punjab Ltd.	0.778	0.87	0.29	0.704
Aries Agro Ltd.	0.798	0.886	0.224	0.89
Asian Fertilizers Ltd.	0.79	0.873	0.303	0.696
Basant Agro Tech (India) Ltd.	0.804	0.879	0.317	0.606
Belsund Sugar & Inds. Ltd.	0.815	0.885	0.278	0.711
Bharat Agri Fert & Realty Ltd.	0.814	0.884	0.316	0.568
Brahmaputra Valley Fertilizer Corpn. Ltd.	0.74	0.823	0.463	0.556
Chambal Fertilisers & Chemicals	0.728	0.85	0.365	0.559
Coromandel International Ltd.	0.771	0.855	0.355	0.576
D C M Shriram Ltd.	0.76	0.849	0.384	0.526
Deepak Agro Solutions Ltd.	0.915	0.928	0.207	0.784
Deepak Fertilisers & Petrochemicals Corpn. Ltd.	0.781	0.878	0.285	0.618
Dharamsi Morarji Chemical Co. Ltd.	0.776	0.872	0.3	0.694
Duncans Industries Ltd.	0.803	0.852	0.505	0.34
Fertilisers & Chemicals, Travancore Ltd.	0.787	0.884	0.298	0.63
Fertilizer Corpn. Of India Ltd.	0.828	0.82	0.725	0.305
G S F C Agrotech Ltd.	0.753	0.86	0.29	0.79
Gammon India Ltd.	0.765	0.864	0.3	0.663
Gujarat Narmada Valley Fertilizers & Chemicals Ltd.	0.762	0.861	0.375	0.492
Gujarat Nitrates Ltd.	0.791	0.883	0.258	0.804
Gujarat State Fertilizers & Chemicals Ltd.	0.775	0.868	0.33	0.579
Harshvardhan Chemicals & Minerals Ltd.	0.822	0.904	0.223	0.84
Hindustan Agro Chemicals Ltd.	0.757	0.862	0.283	0.787
Hindustan Fertilizer Corpn. Ltd.	0.805	0.818	0.67	0.346
Indian Farmers Fertiliser Co-Op. Ltd.	0.78	0.87	0.316	0.619
Indo Gulf Corpn. Ltd. [Merged]	0.752	0.861	0.329	0.63
Indo Gulf Fertilisers Ltd. [Merged]	0.75	0.847	0.331	0.721
Indra Industries Ltd.	0.774	0.858	0.342	0.665
Jai Shree Agro Inds. Ltd.	0.775	0.864	0.307	0.724
Kashi Urvarak Ltd.	0.746	0.851	0.344	0.674
Khaitan Chemicals & Fertilizers Ltd.	0.824	0.89	0.318	0.551
Khushhal Fertiliser Ltd.	0.771	0.859	0.325	0.701
Kothari Industrial Corpn. Ltd.	0.775	0.86	0.346	0.563
Kribhco Shyam Fertilizers Ltd.	0.762	0.856	0.316	0.728
Krishak Bharati Co-Op. Ltd.	0.747	0.845	0.368	0.579
Krishna Industrial Corpn. Ltd.	0.759	0.865	0.295	0.748

Liberty Phosphate Ltd. [Merged]	0.805	0.887	0.312	0.564
Liberty Urvarak Ltd. [Merged]	0.766	0.855	0.332	0.694
M P Agro Inds. Ltd.	0.76	0.86	0.282	0.803
Madras Fertilizers Ltd.	0.816	0.898	0.316	0.45
Mahadeo Fertilizers Ltd.	0.739	0.848	0.318	0.73
Maharashtra Agro-Inds. Devp. Corpn. Ltd.	0.806	0.894	0.363	0.334
Mangalore Chemicals & Fertilizers Ltd.	0.798	0.878	0.305	0.627
Mittal Fertilizers Ltd.	0.765	0.859	0.31	0.735
Monsanto India Ltd.	0.779	0.862	0.336	0.498
Multitech International Ltd.	0.77	0.863	0.304	0.739
Munak Chemicals Ltd.	0.788	0.883	0.242	0.849
Nagarjuna Fertilizers & Chemicals Ltd.	0.708	0.815	0.418	0.656
Nagarjuna Fertilizers & Chemicals Ltd.(Merged)	0.659	0.817	1	0.746
National Fertilizers Ltd.	0.788	0.875	0.334	0.524
Nava Bharath Fertilizers Ltd.	0.792	0.883	0.253	0.819
Ostwal Phoschem (India) Ltd.	0.809	0.875	0.325	0.628
Oswal Greentech Ltd.	0.88	0.927	0.336	0.324
P L Agro Technologies Ltd.	1	1	0.237	0.447
Paradeep Phosphates Ltd.	0.765	0.855	0.358	0.626
Peirce Leslie India Ltd.	0.803	0.873	0.335	0.53
Phosphate Co. Ltd.	0.777	0.864	0.347	0.593
Pragati Fertilizers Ltd.	0.78	0.875	0.272	0.787
Priyaanka Fertilizers & Chemicals Ltd.	0.774	0.867	0.293	0.751
Punjab National Fertilizers & Chemicals Ltd.	0.713	0.828	0.37	0.697
Pyrites, Phosphates & Chemicals Ltd.	0.58	0.712	1	0.371
Raashi Fertilizers Ltd.	0.819	0.889	0.287	0.651
Rallis India Ltd.	0.725	0.858	0.325	0.605
Rama Phosphates Ltd.	0.788	0.874	0.331	0.603
Ramganga Fertilizers Ltd. [Merged]	0.771	0.863	0.307	0.719
Rampur Fertilizers Ltd.	0.751	0.862	0.272	0.846
Rashtriya Chemicals & Fertilizers Ltd.	0.752	0.851	0.383	0.529
Rewati Minerals & Chemicals Ltd.	0.729	0.809	0.526	0.528
S F L Industries Ltd.	0.779	0.88	0.276	0.716
S W A L Corporation Ltd.	0.825	0.917	0.181	1
Shiva Global Agro Inds. Ltd.	0.81	0.893	0.289	0.615
Shree Acids & Chemicals Ltd.	0.74	0.85	0.303	0.783
Shreeji Phosphate Ltd.	0.799	0.872	0.28	0.731
Shri Ganpati Fertilizers Ltd.	0.827	0.887	0.296	0.675
Shriniwas Fertilizers Ltd. [Merged]	0.722	0.84	0.325	0.763
Smartchem Technologies Ltd.	0.847	0.91	0.283	0.601
Southern Petrochemical Inds. Corpn. Ltd.	0.761	0.879	0.283	0.663
Sri Durga Bansal Fertilizer Ltd.	0.753	0.859	0.286	0.802

Sri Krishna Fertilisers Ltd.	0.778	0.856	0.348	0.641
Tata Chemicals Ltd.	0.744	0.842	0.444	0.445
Teesta Agro Inds. Ltd.	0.756	0.848	0.409	0.527
Trimurtee Fertilizers Ltd.	0.762	0.862	0.294	0.76
Tungabhadra Fertilizers & Chemicals Co. Ltd.	0.837	0.908	0.248	0.719
Udaipur Phosphates & Fertilisers Ltd. [Merged]	0.768	0.868	0.29	0.736
Unialkem Fertilizers Ltd.	0.85	0.902	0.243	0.755
V B C Industries Ltd.	0.751	0.86	0.363	0.589
Varinder Agro Chemicals Ltd. [Merged]	0.716	0.834	0.347	0.73
Vivek Fertilizers Ltd.	0.818	0.886	0.279	0.692
Vrundavan Agro Inds. Ltd.	0.813	0.89	0.255	0.792
Zuari Agro Chemicals Ltd.	0.764	0.857	0.35	0.571
Zuari Global Ltd.	0.848	0.912	0.274	0.425

Source: Computed by Author using CMIE Prowess

Let us now discuss the input efficiencies of these Indian fertilizer firms.

We have taken APT Packaging Ltd as the example to explain the various input-specific efficiency scores. From the table 1, the labour efficiency for APT Packaging Ltd is 0.797 on an average. It reflects that on employing 100 units of labour, this company can produce approximately 80 units of output. So, for that company, there is a capacity to produce additional 20 units of output with the same amount of labour. The capital efficiency for APT Packaging Ltd is 0.872 on an average. It means that investing 100 units of capital, this company can produce 88 units of output. So, for that company, there is also a capacity to produce again 12 units of additional output with the same amount of capital. Among the 93 fertilizer companies, the capital efficiency for P L Agro Technologies Ltd becomes the highest as 100 percent on an average. If we look at the energy inputs, the energy efficiency for APT Packaging Ltd is 0.334 on an average. It reflects that employing 100 units of energy consumption, this company can produce 35 units of output. So, for that company, there is a capacity to produce again 65 additional units of output with the same amount of energy. The Nagarjuna Fertilizers & Chemicals Ltd has its highest rank in terms of energy efficiency comparing with others. Any incremental energy expenditure will not give rise to additional output for that company. The materials efficiency for APT Packaging Ltd is 0.568 on an average. Thus, employing 100 units of material consumption, this company can produce 57 units of output. So, for that company, there is a capacity to produce again extra 43 units of output with the same amount of materials. The SWAL Corporation Ltd has its highest level in terms of material efficiency among other fertilizer firms.

Thus, as a whole, the mean efficiency scores for 93 fertilizer firms for materials, labour and capital are 0.64, 0.87 and 0.78 respectively while the mean value of input efficiency for energy is only 0.33 on an average. This differentiation has raised a question regarding such efficient use of labour and capital and inefficient use of energy by the Indian fertilizer firms. This is explained below.

Labour is a factor of production having high average efficiency. Since this sector is a mix of informal and formal firms with seasonal hiring, it doesn’t have restrictions like other manufacturing industries which are stricter in terms of hiring and involuntary attrition. Thus, this sector can cut down the cost of labour when needed. On the whole, therefore, we find that labour efficiency in the fertilizer sector is high. Another important factor of production is capital. On the whole, the efficiency scores for capital reveal that it has a higher score in terms of efficiency. Recently, there seems to be high investment on new machinery, R and D projects etc. in this sector, which maybe driving this high efficiency.

Following the discussion above, among the various inputs, Indian fertilizer industry is not efficient in its energy usage, thus, focus should be on the proper utilization of energy resources. Recently, one of the policies related to this area, called New Economic Policy Scheme (NPS), tried to address this concern. Via this policy, government wanted to provide subsidy only to fertilizer firms which utilize energy resources efficiently. Raw material is also an important factor of production. Well-developed chemical industry ensures smooth supply of raw material to fertilizer industry.

Besides the input-specific efficiency for the industry in aggregate, it is necessary to know it among the firms individually. Now, we can discuss the input-specific technical efficiency from the perspective of size and ownership pattern among the fertilizer firms.

Situation of Input-specific Technical Efficiency from the Perspective of Size Classification

There maybe also differentiation among the firms in terms of their assets which may define their size pattern. Size of a firm is an important factor influencing the type of technology used by a firm. It may also influence its efficiency. Larger firms may have greater capability to diversify their business and scope and that may have a significant impact on technology usage.

Thus, to classify the firms into their various sizes, we needed to create our own definition of large and small firms. This was created based on value of fixed asset of firms. In this paper, we present the data on three groups; large, medium and small. Here, among 93 fertilizer firms, 24 are large-sized, 20 are in medium-sized group and 49 are small-sized. The technical efficiency score is an important indicator of performance of a firm. Following the previous study, from the output perspective, the large firms are generally more technically efficient than the small firms. Next, by the table 2, we can measure the percentage of input-specific technical efficiency score of the fertilizer firms from their size.

Table 2: Average Input-specific Technical Efficiency Score (percentage) from the Perspective of Size of the Firms from 1994 to 2013

Size-wise	Labour Efficiency	Capital Efficiency	Energy Efficiency	Material Efficiency
Large Firms	78	87	34	65
Medium Firms	73	76	38	61
Small Firms	68	63	32	66

Note: Firms with a fixed asset value of less than Rs 55 crore were defined as small-sized firms; firms with a fixed asset value between Rs 110 and 55 crore as medium firms and firms with a fixed asset value more than Rs 110 crore as large firms (based on the value of fixed asset volume data for 2000).

Sources: CMIE PROWESS.

From table 2, the average technical efficiency of the large firms from capital seems to be more, say around 87 percent, and while that in case of energy is low, around 34 percent. This means that the large fertilizer firms may have utilized their capital input more efficiently than other inputs in the production. Capital efficiency seems to have direct correlation with size of firms, as the size increases capital efficiency also increases (due to the larger scale). Large firms give more importance to R&D activities, using superior processes/ technology to produce better products. GSFC Baroda, FEDO Cochin, SPIC Tuticorin, RCF Trombay, GNFC Bharuch etc. are a number of fertilizer producers who have full-fledged R&D centers. In case of small sized fertilizer firms, the labour efficiency is more compared with other inputs, say around 68 percent on an average and the energy efficiency is low (say around 32 percent). That means the small sized fertilizer firms have labour as the only factor which they can influence, hence they are most efficient in their usage. Moreover, after looking at results around inputs efficiencies, it seems that for large, medium and small fertilizer firms, the energy use is more inefficient compared with others. Thus, it should be given more focus for the fertilizer firms in their use of power and fuel properly or to maintain the minimal wastage of their energy usage in the production process. However, the fertilizer industry of India is going through a stage of transition because of various policy changes as it continues to be very much controlled by the Government. The standard classification of firms in terms of ownership type has been threefold – Public-owned firms, Private-owned firms and Cooperative firms. From the previous study, the private sector fertilizer firms are more efficient in output than public firms. To become more efficient, the Indian firms can enter into expensive technological collaboration with private firms. This technological collaboration is a welcome movement for the Indian fertilizer industry over time.

Situation of Input - Specific Technical Efficiency from the Perspective of Ownership Classification

In our study, we will be using the information of sales as key variable from *CMIE Prowess* database for analyzing the ownership pattern of this industry. As per of this classification, the most efficient public sector fertilizer firms are Brahmaputra Valley Fertilizer Corpn. Ltd., Coromandel International Ltd., Fertilizers & Chemicals Travancore Ltd. etc. and the least efficient are Hindustan Agro Chemicals Ltd., Rashtriya Chemicals & Fertilizers Ltd.etc. The most efficient private sector fertilizer firms are Chambal Fertilizers & Chemicals Ltd, Coromandel International Ltd., Deepak Fertilizers & Petrochemicals Corporation. Ltd. etc and the least efficient are Agro Chemical Punjab Ltd, Indo Gulf Corporation. Ltd., Kribhco Shyam Fertilizers Ltd. etc. the cooperative fertilizer firms are Fertilizer Corporation of India Ltd., Krishak Bharati Co-Operative Ltd. etc. Next we can discuss the technical efficiency score from the angle of ownership of fertilizer firms.

Table 3: Average Input Specific Technical Efficiency Score (percentage) from the Perspective of Ownership of the Firms

Ownership-wise	Labour Efficiency	Capital Efficiency	Energy Efficiency	Material Efficiency
Public sector Firms	76	85	42	55
Private sector Firms	78	87	32	67
Cooperative sector Firms	76	86	34	60

Sources: CMIE Prowess.

From this table 3, the average technical efficiency of the public sector firms from capital seems to be more, around 85 percent, while that in case of energy is low, around 42 percent. That means the public sector fertilizer firms have utilized their capital input more efficiently than other specified inputs. In case of private sector fertilizer firms, the capital efficiency is more, around 87 percent, on an average and the energy efficiency is low (32 percent). Moreover, from the table 3, the capital efficiency becomes more in private sector fertilizer firms than in the public sector although the difference is very less. Comparing the four inputs efficiency result, it seems that for public and private sector fertilizer firms, the energy use is much more inefficient compared to others. Thus, the fertilizer firms should focus more on their proper use of power and fuel in the production process. The energy consumption of firms (available in the balance sheet of the companies) reveal that firms that have undertaken the initiative to conserve energy for the production process by replacing the old technology with modern ones, are more efficient ones. The rest of the firms still use technology that consumes more of energy per unit of the output generated and therefore cause energy wastage. It is noteworthy that the share of consumption of power and fuel has increased for the fertilizer sector, from 2 percent to around 23 percent of the total cost of production from 1994 to 2013.

Significance of Energy Efficiency among the Fertilizer Firms

From the literature, it is almost clear that energy consumption may significantly affect the productive performance of firms. Moreover, efficient utilization of these energy resources may be helpful in maintaining higher production performance in the fertilizer sector. The following Table 4 illustrates the name of the top and bottom eight fertilizer firms in terms of their energy efficiency score over 20 years (this is from table 1).

Table 4: Identification of Top eight and Bottom eight fertilizer companies in terms of Energy Efficiency scores (in percentage) estimated from the stochastic random coefficient over (1994-2013) (base period: 2003-04= 100)

Top eight fertilizer firms	Energy Efficiency Scores
Nagarjuna Fertilizers & Chemicals Ltd.(Merged)	92
Fertilizer Corpn. Of India Ltd.	72
Hindustan Fertilizer Corpn. Ltd.	67
Rewati Minerals & Chemicals Ltd.	53
Duncans Industries Ltd.	51
Brahmaputra Valley Fertilizer Corpn. Ltd.	46
Tata Chemicals Ltd.	44
Teesta Agro Inds. Ltd.	41

Bottom eight fertilizer firms	Energy Efficiency Scores
Shreeji Phosphate Ltd.	28
Rampur Fertilizers Ltd.	27
Adarsh Chemicals & Fertilisers Ltd.	26
Nava Bharath Fertilizers Ltd.	25
Munak Chemicals Ltd.	24
Harshvardhan Chemicals & Minerals Ltd.	22
Deepak Agro Solutions Ltd.	21
SWAL Corporation Ltd.	18

Note: A rank of 'zero' for underlying energy efficiency represents the least efficient company by this measure, whereas a rank of 1 represents the most efficient company among the 93 fertilizer firms in total.

Source: CMIR Prowess.

Now, we have categorized the firms into three groups according to their energy use efficiency obtained from the stochastic varying coefficient frontier model. Firms with energy use efficiency of less than 30 percentage are categorized as inefficient, those with efficiency in the interval of 30 percentage to 50 percentage are categorized as medium efficient and firms with energy efficiency more than 50 percentage are categorized as highly efficient.

On the basis of this classification, among 93 fertilizer firms, Nagarjuna Fertilizers and Chemicals Limited (M), Fertilizer Corporation of India Ltd, Hindustan Fertilizer Corporation. Ltd, Rewati Minerals & Chemicals Ltd, Duncans Industries Ltd are the most efficient fertilizer companies in terms of energy use on an average, while Nava Bharath Fertilizers Ltd, Munak Chemicals Ltd, Harshvardhan Chemicals & Minerals Ltd, Deepak Agro Solutions Ltd, SWAL Corporation Ltd etc are the least efficient in terms of energy used. The government has introduced various policies encouraging efficient energy use.

From the ongoing analysis, we did find some correlation between the size of the fertilizer firms and its input specific efficiencies. Large sized firms simply due to their scale, always have a better position in terms of its input use efficiency compared with other sized firms. Since our interest is on energy inputs here. But if we look at the energy efficiency values, it should be noted from the above table 1 that, there may be some firms for which we may find contradictory results. Some large sized fertilizer firms maybe inefficient in terms of energy consumption, like DCM Shriram Ltd, Chambal Fertilizers & Chemicals Ltd, Coromandel International Ltd, and Deepak Fertilizers & Petrochemicals Corporation Ltd and some small size fertilizer firms maybe efficient in terms of energy use like Rewati Minerals & Chemicals Ltd, Teesta Agro Industries Ltd etc.

Now we wanted to study the energy efficiency performance of 93 Indian fertilizer companies using 1994-2013 data. To study it, we have to classify the fertilizer companies with respect to their efficiency in output and energy use.

Identification of Fertilizer Firms which Follow Best Practices in Terms of Energy Efficiency and Output Efficiency

Now, we look at a bivariate distribution between output and energy (see appendix table A2). To study this, we have classified the fertilizer companies by their efficiency in output and energy use. This output efficiency is measured with the help of stochastic ***Frontier 4.1 method*** followed by Khan S (2017). This is proposed for policy makers and business leaders. The classification is based on four categories as follows: Companies with Output Efficient-Energy efficient, Companies with Output Inefficient-Energy Efficient, Companies with Output Efficient-Energy Inefficient and Companies with Output Inefficient-Energy Inefficient. Based on this, we selected five important fertilizer companies from 93 companies for each category. Table 5 given below has highlighted the selected companies.

Table 5: Selected Fertilizer Companies

Companies	Energy Efficient Companies	Energy Inefficient Companies
Output Efficient Companies	Nagarjuna Fertilizers and Chemicals Ltd (Merged)	Rama Phosphate Ltd.
	Indo Gulf Corpn. Ltd.	Multitech International Ltd.
	Tata Chemicals Ltd.	Pyrites, Phosphates & Chemicals Ltd.
	Mangalore Chemicals & Fertilizers Ltd.	Rewati Minerals & Chemicals Ltd
	Chambal Fertilizers & Chemicals Ltd	SWAL Corporation Ltd.
	Coromandel International Ltd	
Output Inefficient Companies	Udaipur Phosphates & Fertilisers Ltd.	Asian Fertilizers Ltd.
	Shree Acids & Chemicals Ltd.	Teesta Agro Inds. Ltd
	D C M Shriram Ltd.	Deepak Agro Solutions Ltd.
	Ramganga Fertilizers Ltd.	Southern Petrochemical Inds. Corpn. Ltd
	Deepak Fertilizers & Petrochemicals Corpn. Ltd.	Mahadeo Fertilizers Ltd.

Sources: CMIE PROWESS

On the basis of this classification, it should become easier for the policy makers to judge the companies properly and then implement the policies more effectively.

Conclusion

Tracking economy-wide input efficiency performance has recently received increasing attention in manufacturing industries. Methodologically, the stochastic varying random coefficient model developed by Kalirajan and Obwona (1994a) shows us that the best practice is to refer to each input separately instead of the whole set of inputs used by a firm. The main point to be noted is that energy-specific technical inefficiency plays a major role in inter-firm efficiency differences of the fertilizer sector. Also, measures of input-specific technical efficiency may be useful for policy purposes. With the help of the study of input specific technical efficiency measurement, the policy planners will have to set targets of different inputs to produce a given level of output and can take the measures to reduce technical inefficiency. Another highlighting issue from this study is that the relation between the size of the fertilizer firm and its consumption per unit of energy in case of fertilizer sector is not effective too much. That means size is always not a significant factor for a firm's energy efficiency measurement.

Appendix Table A1: Summary Statistics for Variables (base year 2004-05=100)

Variables	Mean	Std. Dev.	Min	Max
Output (Q)	7.0192	0.1863	6.7919	7.3194
Labour (L)	5.5537	0.0598	5.4285	5.6605
Capital (K)	6.6580	0.1272	6.4900	6.9008
Energy (E)	5.6779	0.2998	5.3731	6.2333
Material (M)	6.7449	0.1969	6.4991	7.1153

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

Source: Author's computation from CMIE PROWESS database.

Appendix Table A2: Output Efficiency and Energy-specific Efficiency of 93 Fertilizer Companies (in percentage) (base year 2004-05= 100)

Firms	Energy Efficiency	Output Efficiency
A P T Packaging Ltd.	33	78
Adarsh Chemicals & Fertilisers Ltd.	26	77
Agro Chem Punjab Ltd.	29	82
Aries Agro Ltd.	22	76
Asian Fertilizers Ltd.	30	71
Basant Agro Tech (India) Ltd.	32	80
Belsund Sugar & Inds. Ltd.	28	79
Bharat Agri Fert & Realty Ltd.	32	87
Brahmaputra Valley Fertilizer Corpn. Ltd.	46	49
Chambal Fertilisers & Chemicals	37	37
Coromandel International Ltd.	36	83
D C M Shriram Ltd.	38	41
Deepak Agro Solutions Ltd.	21	76
Deepak Fertilisers & Petrochemicals Corpn. Ltd.	29	39
Dharamsi Morarji Chemical Co. Ltd.	30	69
Duncans Industries Ltd.	51	81
Fertilisers & Chemicals, Travancore Ltd.	30	71
Fertilizer Corpn. Of India Ltd.	73	62
G S F C Agrotech Ltd.	29	68
Gammon India Ltd.	30	76
Gujarat Narmada Valley Fertilizers & Chemicals Ltd.	38	87
Gujarat Nitrates Ltd.	26	68
Gujarat State Fertilizers & Chemicals Ltd.	33	81
Harshvardhan Chemicals & Minerals Ltd.	22	77
Hindustan Agro Chemicals Ltd.	28	66
Hindustan Fertilizer Corpn. Ltd.	67	65
Indian Farmers Fertiliser Co-Op. Ltd.	32	81

Indo Gulf Corpn. Ltd. [Merged]	33	86
Indo Gulf Fertilisers Ltd. [Merged]	33	65
Indra Industries Ltd.	34	63
Jai Shree Agro Inds. Ltd.	31	65
Kashi Urvarak Ltd.	34	75
Khaitan Chemicals & Fertilizers Ltd.	32	83
Khushhal Fertiliser Ltd.	33	64
Kothari Industrial Corpn. Ltd.	35	77
Kribhco Shyam Fertilizers Ltd.	32	72
Krishak Bharati Co-Op. Ltd.	37	79
Krishna Industrial Corpn. Ltd.	30	67
Liberty Phosphate Ltd. [Merged]	31	88
Liberty Urvarak Ltd. [Merged]	33	67
M P Agro Inds. Ltd.	28	70
Madras Fertilizers Ltd.	32	39
Mahadeo Fertilizers Ltd.	32	71
Maharashtra Agro-Inds. Devp. Corpn. Ltd.	36	72
Mangalore Chemicals & Fertilizers Ltd.	31	83
Mittal Fertilizers Ltd.	31	62
Monsanto India Ltd.	34	100
Multitech International Ltd.	30	65
Munak Chemicals Ltd.	24	72
Nagarjuna Fertilizers & Chemicals Ltd.	42	65
Nagarjuna Fertilizers & Chemicals Ltd.	100	81
National Fertilizers Ltd.	33	86
Nava Bharath Fertilizers Ltd.	25	67
Ostwal Phoschem (India) Ltd.	33	69
Oswal Greentech Ltd.	34	90
P L Agro Technologies Ltd.	24	82
Paradeep Phosphates Ltd.	36	72
Peirce Leslie India Ltd.	34	89
Phosphate Co. Ltd.	35	74
Pragati Fertilizers Ltd.	27	67
Priyaanka Fertilizers & Chemicals Ltd.	29	66
Punjab National Fertilizers & Chemicals Ltd.	37	61
Pyrites, Phosphates & Chemicals Ltd.	43	69
Raashi Fertilizers Ltd.	29	81
Rallis India Ltd.	33	89
Rama Phosphates Ltd.	33	73
Ramganga Fertilizers Ltd. [Merged]	31	38
Rampur Fertilizers Ltd.	27	65
Rashtriya Chemicals & Fertilizers Ltd.	38	81

Rewati Minerals & Chemicals Ltd.	53	60
S F L Industries Ltd.	28	90
S W A L Corporation Ltd.	18	94
Shiva Global Agro Inds. Ltd.	29	92
Shree Acids & Chemicals Ltd.	30	33
Shreeji Phosphate Ltd.	28	69
Shri Ganpati Fertilizers Ltd.	30	67
Shriniwas Fertilizers Ltd. [Merged]	33	65
Smartchem Technologies Ltd.	28	79
Southern Petrochemical Inds. Corpn. Ltd.	28	85
Sri Durga Bansal Fertilizer Ltd.	29	63
Sri Krishna Fertilisers Ltd.	35	69
Tata Chemicals Ltd.	44	99
Teesta Agro Inds. Ltd.	41	71
Trimurtee Fertilizers Ltd.	29	64
Tungabhadra Fertilizers & Chemicals Co. Ltd.	25	83
Udaipur Phosphates & Fertilisers Ltd. [Merged]	29	34
Unialkem Fertilizers Ltd.	24	72
V B C Industries Ltd.	36	78
Varinder Agro Chemicals Ltd. [Merged]	35	63
Vivek Fertilizers Ltd.	28	85
Vrundavan Agro Inds. Ltd.	26	64
Zuari Agro Chemicals Ltd.	35	95
Zuari Global Ltd.	27	87

Sources: Author's computation from CMIE PROWESS database.

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