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Efficiency in food grains production in India using DEA and SFA

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Abstract:

Aim: Food security is a multi-dimensional issue and is concerned with aspects such as availability, access and utilisation. It would require major interventions that will transform the current patterns and practices of food production, distribution and consumption. Food security can be attained by increasing the level of agricultural productivity and efficiency and improvements in agricultural efficiency are at the core of the quest for food security. This paper seeks to examine the efficiency in food grains production in India for the period 1960-61 to 2013-14.

Design / Research methods: The key idea is to employ the non-parametric Data Envelopment Analysis and the parametric Stochastic Frontier Analysis to measure the efficiency of food grains production in India. We have estimated an input oriented single output, multi – input DEA models (CRS – DEA and VRS- DEA) of agricultural production to measure the efficiency in food grains production for two time periods 1960-61 to 1989-90 and 1991-92 to 2013-14. The analysis of super efficiency was conducted for both these time periods helped identify the years in which food grains production was most efficient.

Conclusions / findings: We find high average efficiency in farming operations for both the frontier methods. However, the range of efficiency obtained varies considerably for the different frontier methods. The period after 1990 has witnessed improved agricultural performance as can be inferred from the frequency distribution of the efficiency scores which indicates that during this period the overall efficiency scores have been higher and there was not a single year in which the efficiency levels have been less than 0.9. The analysis of super efficiency also indicates the improved performance of the agricultural sector in the post 1990 periods as greater number of years recorded an efficiency score greater than 1 as compared to the previous period. However, the super efficiency scores recorded in the period 1961-1990 were higher than those in the post 1990 years suggesting thereby that there could be a tapering of the positive impact of the Green Revolution. Efficiency estimates obtained by the SFA model are marginally lower than that of the DEA model and the results of the SFA model indicate net sown area, net irrigated area and pesticides to be statistically significant inputs.

Originality / value of the article: This study contributes significantly to the literature on efficiency measurement of agricultural production in India by focussing on efficiency measurement of food grains. Most studies focus on farm level data and /or on individual crops.

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Implications of the research: The results of this study have implications for the issue of food security in India. Its results indicate a need to expand irrigation facilities and net sown area to improve efficiency in food grain production which is vital for the issue of food security.

Key words: agriculture efficiency, food grains production, food security
JEL: C6, Q18.

1. Introduction

The Food and Agriculture Organisation's (FAO) vision of a world without hunger is one in which "most people are able, by themselves, to obtain the food they need for an active and healthy life, and where social safety nets ensure that those who lack resources still get enough to eat" (FAO/WHO 2007). Food security is a multi-dimensional concept and includes aspects such as availability (associated with production and trade), access (associated with income and wealth) and utilisation (associated with health and nutrition) (Asenso-Okyere et al. 1997). The Planning Commission Government of India (9th Five Year Plan, vol. II) has also noted that the essential elements of food security encompass adequate availability of food, efficient distribution through trade and / or public distribution system, and availability of adequate purchasing power in the hands of the people. Asenso-Okyere et al. (1997) point out the significance of food security to human welfare and an indicator reflecting changes in human life which has an impact on the food and nutritional situation at the global, national, and household and individual level. From the individual and house hold point of view, food security is concerned with both physical (supply) and economic access to adequate food for all members.

The multiple challenges to food security are rising food prices, population growth, rapid dietary transitions, threats to agricultural production, inefficient production practices and supply chains and a declining investment in agriculture in almost all countries and more so in developing countries. At the global level, food production is adequate to avoid famine and malnutrition but there are wide regional disparities in availability, access and utilization. Further, the overall positive trend at the global level has disguised the disparities in production and distribution of food between regions (Rosegrant et al. 1995; Rosegrant et al. 1997). Consequently, the provision of food security would require major interventions and involve more than one strategy to transform the current patterns and practices of food production, distribution and consumption.

While access to food (which covers the systems and programmes of making food available at affordable prices to citizens) is extremely important; of equal significance are measures that aim at increasing production and improving yields. Increasing production and yields with the available inputs would be the first step in tackling the availability issue in food security. The POST note (2006) examines the causes of food insecurity in developing countries points out that it is not agricultural development alone but also institutional and industrial development that are needed to successfully reduce poverty and food insecurity, but no country has achieved reduction in poverty and food insecurity without first increasing agricultural productivity.

Since Independence the government in India has sought to ensure and maintain food security in the country and a range of policies were implemented to increase the domestic production of food grains along with adequate procurement and storage facilities, maintenance of buffer stocks, provision of minimum support price, an effective public distribution system accompanied by open market sales and periodic import of food grains. One of the major policy initiatives in this direction is The National Food Security Act, 2013 (also Right to Food Act) passed by the parliament of India with the objective of providing subsidized food grains to approximately two thirds of India’s 1.2 billion people. The above act makes into legal entitlements for existing food security programmes of the Government of India. The schemes covered in the programme are the Midday Meal Scheme, Integrated Child Development Scheme, and distribution System, and also the maternity entitlements. The Midday Meal Scheme and the Integrated Child Development Services Scheme are universal in nature whereas the PDS will reach about two-thirds of the population (75% in rural areas and 50% in urban areas). However, in spite of all these efforts, (FAO 2015) notes that India is still home to the highest (194.6 million or 15.2 per cent of the population) undernourished people in the world.

An important aspect of food security is increasing the level of agricultural productivity and efficiency. In other words, improvements in agricultural efficiency form the core of food security and aspects that would need attention are output per hectare, regional variations, technological backwardness, remunerative prices, marketing and delivery systems, low and faulty input uses.

The crucial need to address efficiency in Indian agriculture stems from the fact that it is a sector that almost weaves the economic and social fabric of the country. Pilz and Wilmshofer (2015) emphasise a three point argument supporting the key importance of agriculture in India -first, nearly three-quarters of India’s families depend on rural incomes; second rural areas account for a very large majority of India’s poor (some 770 million people or about 70 percent); lastly India’s food security requires increasing production of cereal crops, as well as that of fruits, vegetables and milk to meet the demands of a growing population with rising incomes. In India, even today almost half of the workforce are dependent on the agricultural sector, but this workforce receives a very small share in the GDP, such that the poor in agriculture have incomes much that lower than their counterparts in industry or services sector. Therefore, it is without doubt that improved performance and incomes in agriculture would impact the fate of the largest proportion of the low-income population in India.

FAO (2009) further points out that by 2050 agriculture would be required to feed 9.1 billion people while at the same time managing issues of climate change, land degradation, bioenergy. The provision of food, feed and fibre, as well as incomes and employment place immense pressure on the agriculture sector. Measuring the efficiency of existing agricultural set- ups would therefore be an important step in maintaining the synergies between agriculture development and food security.

Measuring the efficiency of agricultural production is an important issue in a developing country like India as it is linked to incidence of poverty and nutrition. A time series evidence on rural poverty in India shows that the incidence of poverty fluctuates in response to variations in real agricultural output per head, but there is no significant time trend. There is a statistically significant inverse relationship between rural poverty and agricultural performance for India as a whole, suggesting that agricultural growth by itself tends to reduce the incidence of poverty (Ahluwalia 1978).

The present study therefore is an attempt to examine efficiency in agricultural productivity in India.

2. Review of literature

This section contains studies which examine agricultural efficiency in developing countries and also those related to India. The focus of some studies has been on the efficient use of resources by farmers given the existing agricultural practices (i.e. technical efficiency) while some studies have examined whether farms are operating at the optimal size that guarantee production at the minimum average cost (i.e. scale efficiency) using the non-parametric Data Envelopment Analysis, parametric Stochastic Frontier Analysis and Indexing methods.

Bhatia (1967) constructed an index of agricultural efficiency for 47 districts in Uttar Pradesh for the year 1960-61 for 11 crops. Agricultural efficiency was stated to be a function of various factors that included the physical (climate and soil), socio-economic (size of holding and type of farming), and technical organization (crop rotation, irrigation and mechanization). Data on 11 crops for the period 1960-1961 obtained from official sources was considered. An analysis of spatial variations in efficiency indicated that regions in the north of the State coinciding with the Terai displayed extremely low levels of efficiency while the high agricultural efficiency zone comprised of a long narrow belt running from west to southeast. The results also demonstrated wide disparity in efficiency levels both across crops in a given region as well as across regions within the State. The paper found that high and very low efficiency regions in the State were continuous belts while the medium and low efficiency areas enveloped the high efficiency areas in a somewhat irregular manner.

Coelli and Battese (1996) estimated a SFA model to determine efficiency in production for farm-level data for three villages in the state of Andhra Pradesh, in India. Results indicated substantial variations in farm level efficiencies in the three villages along with a general upward trend in the levels of mean efficiency over the sample period in all three villages. The high variability of the mean efficiencies for the villages at the beginning of the study were contrasted by the convergence in values towards the end of the ten-year period. Factors that influenced efficiency included farm size, age and level of education.

Jha et al. (2000) applied DEA to examine allocative and technical efficiency on a sample of 300 wheat farms in Punjab, India for the years 1981-82 and 1982-83. The findings of the study emphasized that both at the aggregate and individual tehsil level farm size mattered and that aggregate technical and allocative efficiency was greater on large farms as compared to small farms. The paper further suggested that land fragmentation in Punjab needed to be avoided if efficiency was to be improved.

Thiam et al. (2001) conducted a meta-analysis to review empirical estimates of technical efficiency of agriculture in developing countries. A data set of 51 observations of technical efficiency from 32 studies was analyzed in order to ascertain if data specific characteristics and econometric specifications applied in the various studies explained for systematic differences in the efficiency estimates. The Tobit procedure indicated that modelling factors such as primal versus dual, number of fixed inputs and number of variable inputs influenced average technical efficiency estimates. Other factors such as the number of variables in the model, crop type, stochastic versus deterministic frontiers and sample size did not seem to significantly affect estimates of technical efficiency across studies.

Coelli et al. (2002) studied efficiency in farming in Bangladesh during 1997 using a sample of 406 rice farms across 21 villages. Output was measured as kilograms of rice harvested and the input variables considered were land under rice cultivation, family and hired labour, fertiliser, seed and number of draft animals employed. The study observed that though the adoption of rice based green revolution resulted in an increase in rice output from 11,504 thousand metric tonnes in 1968-70 to 18,211 thousand metric tonnes in 1992-94 it has stagnated ever since signifying the need to develop new varieties and improve the efficiencies of the existing technologies. The paper noted that the overuse of fertilizers and labour have resulted in allocative inefficiency. Further, units with better access to input markets and doing less off- farm work tended to be more efficient.

Pujari (2005) estimated DEA as well as SFA models and the Malmquist index to calculate technical efficiency and total factor productivity for cereal crops in Indian agriculture using district level data over twenty-five years 1966-67 to 1994-95 from thirteen major States. Wide inter-State variations in efficiency were observed for all cereal crops. The results showed that irrigation, bullock, fertilizers, tractors had a positive impact on yield whereas labour in all crops showed a negative impact on yields. The results also pointed to the importance of availability of infrastructure facilities like market density, road density, and rural bank branch and literacy rate in improving efficiency of cereal production.

Murthy et al. (2009) estimated technical and scale efficiencies using DEA and log linear regression models for tomato-producing farms in Kolar and Bangalore rural districts of Karnataka. Three farm sizes, viz. small, medium and large were considered. Technical inefficiency was pervasive across farms irrespective of the size of holding. The medium farms exhibited highest level of technical efficiency which could be explained by factors such as land and labour productivity and education. Small farms, on the other hand, were price-efficient in terms of lower cost on production (Rs1.72/kg compared to Rs2.01 in medium farms and Rs1.85 in large farms) and hence enjoyed higher unit profit. The existence of increasing returns to scale in a majority of farms pointed to the potential for expanding production and productivity and thereby increasing technical efficiency. The paper found that the inability of the farmers to fully exploit the available technologies as the major cause for low productivity.

Poudel et al. (2011) used DEA to measure technical efficiency in a random sample of 240 coffee growers (120 conventional and 120 organic farmers) in two districts of Nepal. The paper indicated no major difference in mean technical efficiency scores of organic (0.89) and conventional (0.83) farmers. The results of the Tobit regression indicate that the differences in technical efficiency were related to education, farm experience and training/extension services and access to credit. Besides, technical efficiency was positively correlated to household size, farm experiences in input/output use, credit for investment and adoption of technical know-how on farming system management.

Ray and Ghose (2014) applied Data Envelopment Analysis to obtain Pareto-Koopmans measures of technical efficiency for a multi-output, multi-input model of agricultural production covering food grains and non-food grains for 17 States in India for the period 1970-71 to 2000-01. The output variable was the production of food grains and non-food grains while inputs included were land, fertilizers, irrigated area, pump sets, tractors, electricity and labour. The disaggregated input and output efficiencies showed a declining trend over time. The paper found that though the adoption of modern technology necessitated increased use of fertilizers and agricultural machinery, the potential benefits of the technological revolution remain largely unrealized because of the inabilities for the productive utilization of the inputs.

3. Methodology

Most studies which examine and analyze efficiency have used a combination of different methods such as the index methods, Data Envelopment Analysis, Stochastic Frontier Analysis along with Tobit models and Two Stage Least Squares (2SLS). The economic theory on which efficiency analysis is based derives from the seminal work of Koopmans (1951) and Debreu (1951) on activity analysis and on Farrell (1957) influential *The Measurement of Productive Efficiency*. Farrell was highly influenced by the measure of technical efficiency developed by Koopmans and Debreu and further proposed that technical efficiency of a firm can be decomposed into - pure technical efficiency (TE) which would reflect the ability of a firm to obtain maximum output from a given set of inputs under a given technology and allocative efficiency (AE) which would reflect the ability of a firm to use its inputs in optimal proportions, given their respective prices and the production technology. These two measures of efficiency can then be combined to provide a measure of total economic efficiency. Thus, in the Farrell approach, inefficiency of a productive unit can either be because it is obtaining less than the maximum output available from a determined group of inputs (technically inefficient) or by not purchasing the best combination of inputs given their prices and marginal productivities (allocative inefficiency). Most recent studies have measured performance using frontier functions either parametric or non-parametric.

Data Envelopment Analysis (DEA) is a non-parametric linear programming technique that measures the efficiency of a decision-making unit (DMU) such as a firm or a public-sector agency and identifies the best practice frontier, first introduced into the operations research literature by (Charnes et al. 1978) to evaluate non-profit and public sector organizations. A major advantage of DEA is that it does not require the specification of a functional relationship between inputs and outputs and other restrictions though it may not necessarily account for statistical noise and has the ability to simultaneously handle multiple inputs and multiple outputs without any specifications of their relative importance. Performance measures that study multiple input and output models are of importance to policy makers since it indicates the extent to which a particular industry or company can be expected to increase its multiple output and decrease its input levels by merely improving its efficiency (Zhu 2000). The DEA model initially developed by Charnes Cooper and Rhodes and known as the CCR model assumed that operations follow constant returns to scale and was modified by (Banker et al. 1984) to handle variable returns to scale. The modified models are referred to as the BCC DEA models. The CRR and BCC models enable a distinction to be made between two kinds of efficiencies-technical and scale efficiencies given that each of these models have a different set of assumptions. The CRR model provides estimates of gross efficiency of a DMU under the assumption of constant returns-to-scale (CRS) and the efficiency measure is known as overall technical efficiency (OTE). The OTE can further be decomposed into two mutually exclusive and non-additive components - pure technical efficiency (PTE) and scale efficiency (SE). Pure technical efficiency describes the efficiency in converting inputs to output, while scale efficiency recognizes that economies of scale cannot be achieved at all possible scales of production and that there is one most productive scale size, where the scale efficiency is 100 percent. The technical efficiency of a DMU is therefore a comparative measure of how well it actually processes inputs to achieve its outputs, as compared to its maximum potential for doing so, which is given by the production possibility frontier (Barros, Mascarenhas 2005). A DMU, thus, will be deemed as technically inefficient if it operates below the frontier. The BCC model captures the variation in efficiency considering the scale of operation under a less restrictive variable returns to scale (VRS) technology (VRS), and provides an alternative measure of *technical efficiency* referred to as the VRS efficiency and is given by the ratio of OTE to PTE (Dhungana et al. 2004). The PTE can be measured from the efficient frontier under the assumption of variable returns-to-scale.

Let x and y represent inputs and outputs and i and j represent particular inputs and outputs respectively. Hence, xi and yj would imply the ith input and jth output of a decision making unit (DMU). The total number of inputs and outputs are represented by I and J where I, J > 0.

A general output oriented CCR DEA model can be represented as:

$$\max z = \sum_{j=1}^{J} v_{jm} y_{jm}$$

$$s.t.$$

$$\sum_{i=1}^{I} u_{im} x_{im} = 1 \qquad (1)$$

$$\sum_{j=1}^{J} v_{jm} y_{jm} - \sum_{i=1}^{I} u_{im} x_{im} \leq 0; m = 1,2,....M$$

$$v_{jm}, u_{im} \geq \varepsilon; i = 1,2,.....I; \ j = 1,2,......J.$$

A general input oriented CCR DEA model can be represented as:

$$\min z' = \sum_{i=1}^{I} u'_{im} x_{im}$$

$$s.t.$$

$$\sum_{j=1}^{J} v'_{jm} y_{jm} = 1 \qquad (2)$$

$$\sum_{j=1}^{J} v'_{jm} y_{jm} - \sum_{i=1}^{I} u'_{im} x_{im} \leq 0; m = 1,2,.......M$$

$$v_{jm}, u_{im} \geq \varepsilon; i = 1,2,........I; \ j = 1,2,.........J.$$

Variable returns to scale – BCC Model

The VRS formulation was first suggested by Banker et al. (1984) and hence is referred to as the BCC DEA or VRS DEA model. This model can be represented as follows:

$$\min z' = \sum_{i=1}^{I} u'_{im} x_{im}$$

$$s.t.$$

$$\sum_{m=1}^{M} y_{jm} \lambda_m \geq y_{jm}$$

$$\sum_{m=1}^{M} x_{im} \lambda_m \leq \sum_{m=1}^{M} u' x_{im} \qquad (3)$$

$$\sum_{m=1}^{M} \lambda_m = 1$$

$$\lambda \geq 0.$$

The Constant Returns to Scale (CRS) efficiency is obtained by removing the convexity constraints from equation 3. The CRS model estimates gross efficiency of a DMU which is a composite of technical and scale efficiency. The efficiency of transforming inputs into output denotes technical efficiency while scale efficiency estimates that most productive scale size where the scale at which efficiency is 100 percent. The BCC model measures Variable Returns to Scale (VRS) efficiency. This model takes into consideration the variation in efficiency with respect to the scale of operation and therefore measures pure technical efficiency. The scale efficiency of a DMU can be calculated as the ratio of its CRS to VRS efficiency.

In the CRS model the inputs and outputs will be scaled up and down with the same proportions whereas in the VRS a scaling up of inputs may not lead to an equi-proportionate increase in output. Scale efficiency can be used to measure the loss from not operating at optimal scale size (Bogetoft, Otto 2011).

Stochastic frontier analysis

Given a general production function of the form $f(x_i, \beta)$, then in the absence of any inefficiency the output of the ith firm would be represented by

$y_i = f(x_i, \beta)$ (4)

Where; y_i= output x_i = vector of inputs and β is a vector of parameters to be estimated.

Hence the level of output given by equation (9) would represent technically the maximum potential output that can be achieved by the firm.

The Stochastic Frontier Model (SFA) model takes into account the effects of inefficiency and hence a given firm maybe actually be producing less than the optimal level and the production function may then be represented as:

$y_i = f(x_i, \beta) + e_i, i = 1, \ldots.., N$ (5)

where $e_i = v_i - u_i$, is a composite of two terms:

(i) v_i is a normally distributed error term representing measurement and specification error or noise and represents factors beyond the control of the firm; $v_i N(0, \sigma_v^2)$

(ii) u_i is a one-sided error term which represents inefficiency i.e. the inability to produce the maximum level of output given the inputs used. The component *ui* is assumed to be distributed independently of *vi* and to satisfy *ui* ≥ 0. The non-negativity of the technical inefficiency term reflects the fact that if *ui* > 0 the unit (firm or country or state) will not produce at the maximum attainable level. The generalization of the specification of u_i by Battese and Coelli (1988) is given by

U ~ $N[0,\sigma^2_u]$.

A measure of inefficiency can be obtained by means of the parameter γ which is defined as

$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$ (6)

where, σ_u^2 and σ_v^2 are the variances of the noise and inefficiency effects, respectively.

The value of γ lies between 0 and 1. If it is close to zero then deviations from the frontier can be attributed to noise, while, if the value of γ is close to 1, then deviations from the frontier can be attributed to technical inefficiency (Battese, Corra 1977; Coelli et al. 2005).

Another measure of inefficiency discussed by is given by (Aigner et al. 1977) is lambda.

i.e $\lambda^2 = \sigma_u^2 / \sigma_v^2$ (7)

For the data considered in this paper all India food grains production is taken as a function of net sown area, net irrigated area, fertilizer, pesticides.

4. Empirical Evidence

The paper has employed both the non-parametric Data Envelopment Analysis (DEA) and parametric SFA approaches to assess the technical efficiency of food grain production at the all India level for the period 1960-61 to 2013-14. The paper has estimated a single-output, multi-input model of agricultural production using data from the Reserve Bank of India, Handbook of Statistics on Indian Economy. The output variable is total food grains production (measured in Million tonnes) while the input variables considered are: net sown area (million hectares), net irrigated area (million hectares), fertilizers (N+P+K in million tonnes), and pesticides (million tonnes). Table 1 presents the summary statistics of the input and output variables for the All India data.

Table 1. Descriptive statistics of inputs and output variables

Variable	Minimum	Maximum	Mean	Standard Deviation	Co-efficient of variation
Net sown area	131.9	143	145	2.45	1.74
Net irrigated area	24.88	66.1	45.24	13.07	28.9
Fertilizers	0.34	28.12	10.86	8.39	7.73
Pesticides	0	0	0	0	0
Fertilizers per hectare of net sown area	0.02	0.05	0.03	0.09	2.82
Pesticides per hectare of net sown area	Negligible	Negligible	Negligible	Negligible	Negligible
Total food-Grains production	629	2129	1278	438.27	34.28

Source: Authors' own elaboration.

The average annual output of total food grains is 1278 million tonnes with a standard deviation of 438.27 which shows large variability in production of total food grains in the country during the given time period. The coefficient of variation of total food grains output is 34.28. The above results also indicate that on an average fertilizer is an input which records maximum consumption at 108.58 lakh tonnes whereas pesticides use is an average of 44.36 thousand tonnes. However, no major difference can be observed between average fertilizer consumption and pesticide consumption per hectare of net sown area which is at 0.322 lakh tonnes and 0.3154 thousand tonnes per net sown area. The average net irrigated area is also very low at 45.24 million hectares for the entire country and which actually amounts to 32.23 percent of net sown area.

4.1 Results of DEA

The input oriented DEA model seeks to answer the question: *By how much can inputs be reduced to produce the same level of output*? A summary of efficiency estimates obtained from the DEA and SFA models is presented in Table 2.

Table 2. Summary of efficiency estimates: DEA Models

Statistic	VRS-DEA	CRS-DEA
Mean	0.98	0.95
Minimum	0.95	0.82
Maximum	1	1
Standard Deviation	0.02	0.04
Co-efficient of Variation	15.31	4.39
Skewness	-0.14	-0.81

Source: Authors' own elaboration.

The summary of efficiency estimates for the all India data on total food grains production indicates that for the VRS and CRS models, the mean technical efficiencies are 0.98 and 0.95 respectively and the corresponding standard deviations are 0.01 and 0.04 indicating thereby the presence of considerable efficiency in farming operations. In order to better understand the variations in agricultural efficiency the entire period 1960-61 to 2013-14 has been divided two phases to coincide with the pre-reforms (1960-61 to 1990-91) and post -reforms period (1991-92 to 2013-14). Such an analysis would help examine changes in efficiency, if any, in the country's agriculture sector and would also provide better insights into the factors influencing agricultural productivity in India. The results of the DEA estimation for the two periods is presented in Table 3.

Table 3. Summary of efficiency estimates of the DEA Models

	1961-62 to 1990-91		1990-91 to 2013-14	
Statistic	CRS-DEA	VRS-DEA	CRS-DEA	VRS-DEA
Mean	0.95	0.99	0.96	0.99
Minimum	0.84	0.95	0.96	0.96
Maximum	1	1	1	1
Median	0.97	0.99	0.96	1

Source: Authors' own elaboration.

The above table indicates that the productive efficiency in Indian agriculture is marginally higher in the post reforms period where the mean VRS efficiency at 0.994 is higher than that in the previous period where the same is at 0.985. Further, the median score in the second-time frame is higher at 1 as compared to 0.98 for the corresponding VRS score in the earlier time period. It therefore appears that the post-reforms phase has registered an improvement in agriculture from the productivity and efficiency perspective.

An in-depth analysis of the efficiency can be obtained from the frequency distribution of technical efficiency scores for each of the two periods (Table 4)

Table 4. Frequency distribution of technical efficiency – DEA Models

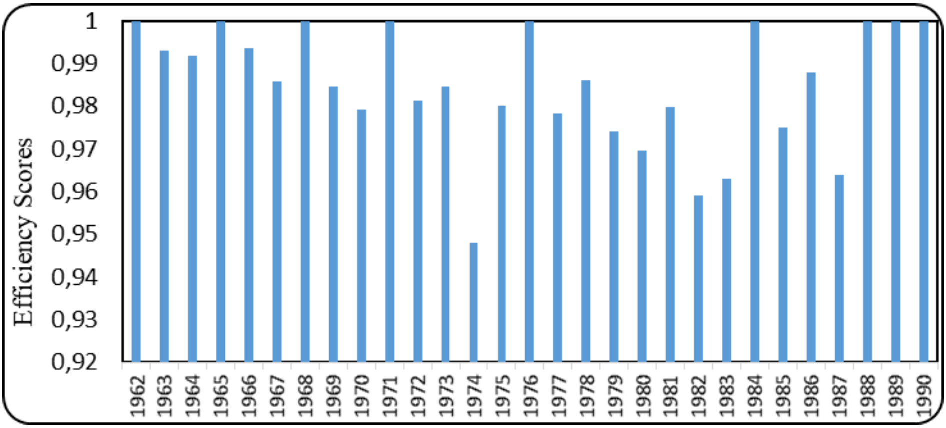
	1961-62 to 1990-1991		1990-91 to 2013-14	
Efficiency Range	CRS DEA (No of years, %)	VRS DEA (No of years, %)	CRS DEA (No of years, %)	VRS DEA (No of years, %)
0.8<=E<0.9	3 (10)	Nil	Nil	Nil
0.9<=E	18 (62)	20 (69)	18 (75)	11 (46)
E=1	8 (28)	9 (31)	6 (25)	13 (54)

Source: Authors' own elaboration.

It can be observed that in the period after 1990, the overall efficiency scores are better and there is not a single year in which the efficiency levels have been less than 0.9. The post reforms era can thus be seen as that of improved agricultural performance and efficiency scores attaining a higher minimum level. The CRS DEA indicates that for 18 years (75%) from a total of 29 years considered the technical efficiency is seen to be greater than or at least equal to 0.9. Similarly, for the same period 13 years are indicative of hundred percent efficiency in productivity under the VRS DEA. In contrast the earlier time phase up to 1990 speaks of relatively lesser performance in agriculture sector since only a total of 9 years (31%) report a technical efficiency level of 100% under the VRS DEA.

A graphical presentation of the efficiency achieved in each year of the pre-and post-reform period is presented in Figures 1 and 2.

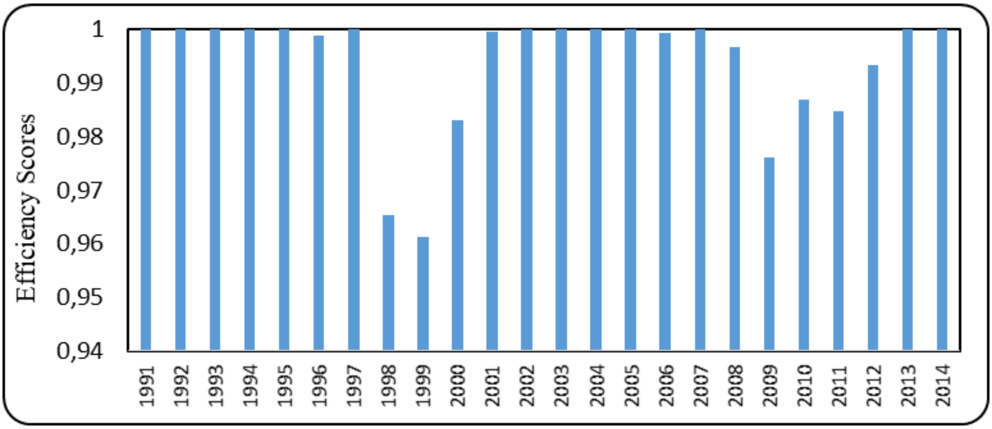
Figure 1. VRS efficiency: 1962-1990



Source: Authors' own elaboration.

An analysis of the efficiency scores shows that efficiency in food grain production is low in 1974 and similar levels of efficiency can be observed are seen in 1982, 1983. These years of low efficiency also coincide with drought years in the country. The years 1962, 1971, 1976, 1988 to 1990 are seen as periods of relatively good efficiency in performance.

Figure 2. VRS efficiency: 1991-2014



Source: Authors' own elaboration.

In the post reforms era, up to 1995 there has been hundred percent efficiency in agriculture at the all India level. However, the years 1998 and 1999 have also witnessed a steep decline in efficiency. Likewise, in the period after 2000, 2009 being a drought year has seen a decline in efficiency. –Besides, the period 2009 - 2012 also indicate a decline in the efficiency scores. A comparison of the efficiency scores in the two periods – pre-and post-reform shows a wide variation in efficiency in the pre-reform period and only 9 of the 29 years (a third of the years) show an efficiency of 1 whereas greater uniformity in efficiency is observed in the post reform period 14 of the 24 (58 percent of the years) years show an efficiency score of 1 in food grains production in the country.

The standard DEA approach classifies DMUs as efficient or inefficient based on the efficiency score obtained by the DMU. All DMUs with a score of unity are classified as efficient, however, all efficient DMUs may not have the same performance level. Hence a disaggregation of the efficiency scores of the efficient DMUs can be done using different methods such as the super efficiency approach (Andersen, Petersen 1993); cross evaluation (Green et al. 1996) or assurance regions method (Cooper et al. 1999). Such methods of decomposing the efficiency score of the optimal units were developed initially by Banker and Gifford (1988), and Banker et al. (1989). Super efficiency estimates consider the possibility of a DMU increasing its inputs and/or reducing its outputs without becoming inefficient. Such an approach will help rank the efficient DMUs. The super efficiencies help determine the difference in efficiency among the efficient DMUs. For the years of greater efficiency in performance the super efficiencies would extend beyond one.

For the data that we have considered, the years and the corresponding super efficiency scores are presented in the table below.

Table 5. Super efficiency scores

Year	Super Efficiency	Year	Super Efficiency
1962	1.66	1991	1.04
1965	1.15	1992	1
1968	1.01	1993	1.02
1971	1.15	1994	1.03
1976	1.19	1995	1
1984	1.02	1997	1.02
1988	1.05	2002	1.04
1989	1.09	2003	1.07
1990	Inf	2004	1.01
		2005	1.03
		2007	1.03
		2013	Inf
		2014	1.02

Source: Authors' own elaboration.

Table 5 shows that in the period after 1991, greater number of years record super efficiencies in agricultural production as compared years before 1991. The highest level of super efficiency is recorded in the year 1962 at 1.66 Also, the range for the super efficiency is much lesser in the period after the 1990s while the range is much greater for the period until 1990 indicating a stable level of performance at a higher level in the period after 1990.

For the post reforms data, the super efficiency reaches a peak level of near 1.07 in 1991. For the years 1992-1995 also efficiencies are greater than one. The years 2003-2005 also indicate super efficiency in production.

4.2 Results of SFA

The mean efficiency measure of the SFA model at 0.94 is closer to the efficiency achieved under CRS DEA. Further the mean efficiency under VRS DEA is greater than that obtained from the SFA model and from the CRS DEA approach. The highest variability in technical efficiency scores is observed in the VRS DEA model. Further, the DEA models exhibit a higher variability than the SFA model.

Table 6. Summary statistics: SFA Model

Statistic	
Mean	0.94
Minimum	0.80
Maximum	0.99
Standard Deviation	0.04
Co-efficient of Variation	4.69
Skewness	-6118

Source: Authors' own elaboration.

Technical efficiency under all three models shows a wide range of variation among the respondents – the VRS (0.44 to 1), CRS (0.052 to 1) and SFA (0.15 to 0.98) with the largest variation for the CRS model.

Table 7. Results of the SFA Model

Variable	**Co-efficient**	**Z values**
Constant	-1.56	-1.36
Net sown area	0.99 ***	5.28
Net irrigated area	1.07***	8.41
Fertilizers	0.05	1.05
Pesticides	-0.11	-3.94
Gamma	1.00***	206.32
σ^2	0.01	
Log likelihood	94.64	
*** = z < 0.001; ** = z< 0.01; * = z< 0.05 and.= p <0.1		

Source: Authors' own elaboration.

The maximum likelihood estimates of the stochastic frontier model are given in Table 7. The results indicate that four inputs, namely, net sown area, net irrigated area and pesticides are statistically significant. The positive and statistically significant co-efficient for net sown area, net irrigated area indicate that a 1 percent increase in net sown area would increase output by almost 1 percent, while a one percent increase in net irrigated area would increase output by another one percent. The negative and significant co-efficient on pesticides point towards an inverse relationship between output and this input. Thus, a decline in pesticides would positively increase total food grains production. The value of gamma is one which suggests that inefficiency in agriculture is purely on account of technical inefficiency and the impact of statistical noise is zero.

6. Conclusion

The paper has measured efficiency in agricultural production in India for the period 1960-61 to 2013-14. The results indicated to the presence of considerable efficiency in farming operations for both the frontier methods. The mean efficiency obtained under the SFA model was closer to the efficiency achieved under CRS DEA model. A wide variation in efficiency was also seen for the different frontier methods and the largest variation was observed for the CRS model over this period. The analysis of efficiency under the DEA model for the two sub periods – 1960-61 to 1989-90 and 1990-91 to 2013-14 indicated to a marginal increase in productive efficiency in food grains production in the period 1990-91 to 2013-14. Further, the period after 1991 witnessed super efficiencies for a greater number of years. The results of the SFA model pointed out net sown area, net irrigated area and pesticides to be statistically significant inputs. The results indicated a negative and significant coefficient for pesticides thereby indicating that a possible reduction in pesticide may help increase efficiency. It can, thus, be concluded, that the effects of the Green Revolution which significantly improved efficiency in agriculture during the mid-1960s seem to be tapering off. An improvement in agricultural efficiency can take place from increased investments in irrigation for the country as a whole since only

32 percent of the net sown area is currently irrigated. The Prime Minister's initiative to improve and upgrade irrigation and make every drop useful through the Sinchai Yojana can provide the much-needed boost to agricultural production in the country. Improvements in efficiency and productivity will have a positive impact on food security.

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