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Estimating Production Efficiency in Rice Cultivation of Bihar: An Economic Approach

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ABSTRACT

Data Envelopment Analysis (DEA) has been widely used in measuring agricultural production efficiency. The present paper is to investigate the technical, allocative and cost or economic efficiencies of rice farms in Bihar. The farm level data used in the analysis was taken from cost of cultivation scheme, Government of India running in the state from 45 *tehsils* of Bihar. Rice is a staple food and consumed by large population of the state, nation and world level. The technical efficiencies, allocative efficiencies of most of the farms were found to be 62% separately for each. Accordingly the degree of cost efficiency was estimated to be only 38.8%. Although, TE and AE being only 62%, farmers are still inefficient to achieve upto the optimal level of output. Given the available technology, farmers may reduce the paddy production cost by 61.2% to produce given level of output at least cost. Tobit analysis was carried out to assess the factors influencing efficiencies revealed that lack of education, quality seeds, and irrigation machinery were found to impact the efficiencies. Government and other policy making agencies have to formulate policies favourable to transform agriculture sector profitable which can attract the educated youth towards agriculture as profession. There is ample opportunities to minimize the cost of paddy production using a given level of technology coupled with proper and timely application of inputs, right combination of inputs with input and output prices to produce a given level of output at least cost. Besides assured supply of good quality seed, irrigation facilities, dissemination of new farming technologies, better education system and financial assistance, marketing infrastructures should be arranged timely so as to enhance the income of rural masses, and to reduce the poverty from the rural areas of the state in general and nation in particular.

Keywords: Data envelopment analysis, technical, allocative, cost efficiency, production, rice

Rice is the most widely consumed staple food for a large part of the world's human population, especially in Asia. Nearly 90% of the world's rice is produced and consumed in this continent (Rai, 2009 and Van Nguyen & Ferrero, 2006). About four - fifths of the world's rice is produced by small - scale farmers and is consumed locally. It is the agricultural commodity with the third-highest worldwide production, after sugarcane and maize, according to (FAOSTAT, 2012) data.

Rice is one of the most important food crops of India in terms of both area, production and consumer preference and it is staple food for more than 65 per cent of its population. India is the second largest producer of rice in the world after China, accounting for 20% of all world rice production. However, India is not only a largest producer of rice but also it is the biggest consumer of rice in the world. It occupies about 22 per cent (43.2 million ha) of the total cultivated area in the country. It is grown mainly by small-scale farmers for cash and food. Rice is India's pre-eminent crop, and is the staple food for the people of the eastern and southern parts of the country. Rice is mainly grown in areas that receive heavy annual rainfall. That is why; it is fundamentally a *kharif* crop in India. India also holds the largest agricultural land for paddy production in the world.

Among all the states, Bihar is major rice growing state in India. Agriculture is the vital source of income and employment in Bihar. 77% of its population is engaged in agricultural pursuits. Bihar has a total geographical area of about 94.16 lakh hectares, out of which only 52.52 lakh hectares is the net cultivated area and gross cultivated area being 75.80 lakh hectares (Economic survey of Bihar, 2016-17). Agriculture and allied sector accounts for 18.1% (2016-17) of the state GDP (including forestry and fishing). Rice is cultivated in almost all 38 districts of Bihar. It has about 3.23 million ha area under rice cultivation, with production of 6.80 million metric tonnes during 2015-16, the state's average productivity is about 2104 kg/ha. More than 90 per cent of farm households belong to marginal farm category (less than 1 ha land) but own about 44 per cent of cultivated land in Bihar. Agriculture sector experienced a drastic change with respect to declining net sown area as a result of increasing population pressure and erratic climatic condition. No doubt, state has got self-sufficiency in food grains but the economic condition of farming community is still miserable. Despite the fertile land and availability of groundwater for irrigation, economic conditions of farmers are still in infant stage. There may be one of the avenues/ways for income generation, by improving productivity by efficient use of inputs and natural resources and available agricultural technologies. The measurement of production efficiency is a vital tool from standpoint of agricultural production and development, as it gives pertinent information which is important for making sound management decision, resource allocation and for formulation of agricultural policies. Hence, this investigation was undertaken with two important objectives. First, we investigate the individual farm's technical, allocative and cost efficiency. Second, we aim to assess the effects of several explanatory variables on rice farming in the state. Accordingly DEA model was used to measure the efficiency level and Tobit model to investigate the impacts of different explanatory variables on rice farming efficiencies.

DATABASE AND METHODOLOGY

Resource Use Efficiency: For calculating resource use efficiency, farm level data of Comprehensive Cost of Cultivation Scheme for the block period 2008-09 to 2010-11 collected from 450 farmers from 45 clusters in Bihar were used. A sample size of 430 paddy growers from different agro-climatic zones of Bihar have been used for this investigation and they were categorized as marginal (< 1 ha), small (1-3 ha), medium (3-5 ha) and large (5 ha and above). DEA is a well established approach for measuring the relative efficiency of peer decision making units (DMUs) that have multiple inputs and outputs, proposed by Charnes *et al.* (1978) and extended by Banker *et al.* (1984). Performance analysis is a relative concept (Coelli *et al.*, 1998). It relates to production analysis and measures the production with a ratio.

Efficiency of resource use which can be defined as the ability to derive maximum output per unit of resource is the key to effectively addressing the challenges of achieving food security. There are various techniques and methods to examine resource use efficiency such as Data Envelopment Analysis (DEA), Stochastic Frontier (SF) production function etc. In the present study, DEA method has been used which is given below:

Data Envelopment Analysis (DEA) approaches: Resource use efficiency under different crop production is estimated on the basis of DEA. DEA is a Linear Programming technique for constructing a non-parametric piece wise linear envelop to a set of observed output and input data. Efficiency is defined as a measure of how efficiently inputs are employed to produce a given level of output producing same level of output, with lower level of inputs or more output with the same level of inputs means higher level of efficiency. The technique of DEA has been used to find the relative efficiency score of each farm in relation to farms with minimum input output ratio for all inputs. The score of the most efficient farms being one, the score of each farm will lie between zero and one.

The variables used in efficiency measures are output of paddy (q/ha) and inputs like working hours of human labour (per hectare), working hours of machine labour (per hectare), NPK quantity (kg/ha), quantity of seed (Kg/ha) and groundwater draft for irrigation (cum/ha) and their per unit costs were used to measure technical, allocative and cost efficiencies of rice production in the state.

In order to specify the mathematical formulation of model, we assume that we have K farmers Decision Making Units (DMU) using n inputs to produce m outputs. Inputs are denoted by x_{jk} (j = 1,2,….. n) and output are represented by Y_{ik} (i = 1,2,3…..m) for each farmer k (k = 1,2,…. K). The technical efficiency (TE) of the farmers can be measured as:

$$TE_K = \sum_{i=1}^{m} u_i y_{ik} / \sum_{j=1}^{n} v_j x_{jk}$$

Where, Y_{ik} is the quantity of i^{th} output produced by k^{th} farmer, x_{jk} is the quantity of j^{th} input used by the k^{th} farmer, u_i and v_i are the output and input weights respectively. The farmer maximizes the technical efficiency, TE_k subject to:

$$TE_K = \sum_{i=1}^{m} u_i y_{ik} / \sum_{j=1}^{n} v_j x_{jk} \leq 1$$

Where, u_i and $v_j \geq 0$

The above equation indicates that the technical efficiency measure of a farmer cannot exceed one, and the input and output weights are positive. The weights are selected in such a way that the farmer maximizes its own technical efficiency which is executed separately. To select optimal weights, the following linear programming model is specified:

Min TE_k

Subject to,

$$\sum_{i=1}^{m} u_i y_{ik} - y_{ik} + \omega \geq 0$$

Where k = 1,2,………..k

$$x_{jk} - \sum_{j=1}^{m} u_j x_{jk} \geq 0$$

and u_i and $v_j \geq 0$

The above model shows TE under constant returns to scale (CRS) with an assumption if w = 0 and it changes into variable returns to scale (VRS) if w is used unconstrained. In the first case it leads to technical efficiency (TE) and in second case pure technical efficiency (PTE) is estimated. Here the analysis is concerned with the first case.

Technical Efficiency (TE): It can be expressed generally as the ratio of sum of the weighted outputs to sum of weighted inputs. The value of technical efficiency varies between zero and one; where a value of one implies that the DMU is the best performer located on production frontier and has no reduction potential. Any value of TE lower than one indicates that DMU uses inputs inefficiently.

Cost or Economic Efficiency (CE): one can measure both technical and allocative efficiencies to verify the behavioral objectives such as cost minimization or revenue maximization.

Cost minimization DEA is expressed as,

Min$Y_{Xk}{}^{*} w_k{}' X_k{}^{*}$,

Subject to $-y_k + Y\ Y \geq 0$,

$X_k{}^{*} - XY \geq 0$,

$Y \geq 0$,

Where $w_k{}'$ is a vector of input prices for the k^{th} farmer and $X_k{}^{*}$ (which is calculated by LP) is the cost minimizing vector of input quantities for the k^{th} farmer, given the input prices w_k and the output level y_k.

Total cost efficiency (CE) or economic efficiency of the k^{th} farmer can be calculated as,

$$\text{CE} = w_k X_k{}^{*} / w_k X_k$$

That is the ratio of minimum cost to the observed cost.

While the allocative efficiency (AE) is calculated as the ratio of cost efficiency to technical efficiency

$$\text{AE} = \text{CE/TE}$$

DEA is well established approach for measuring the relative efficiency of decision making units (DMUs) that have multiple inputs and outputs. We have used this method to investigate the technical efficiency (TE), allocative efficiency (AE) and cost efficiency (CE) or economic efficiency (EE). In this study, we use input-oriented efficiency measures because they reflect local reality where a decrease in scarce resources (inputs) makes use more relevant.

Efficiency or performance analysis is a relative concept relates to production analysis and measures the production with ratio. TE relates the degree to which a farmer produces maximum output from a given bundle of inputs, or uses the minimum amount of inputs to produce a given level of output when the technology exhibits constant returns to scale but is likely to differ otherwise. These two definitions of TE are known as output-oriented or input-oriented efficiency measures, respectively. AE or price efficiency reflects the ability of a farm to use the inputs in optimal proportions, given their respective price EE or CE is distinct from the other two; even though it is the product of TE and AE and reflects the ability of a production unit to produce a well-specified output at minimum cost. An economically-efficient might be both technically and allocatively efficient.

Table 1: Variable's definition for identifying the factors associated with efficiency

Variables	Definition
Age	Age of the farmers (years)
Education (AG)	50 Illiterate, 51 Up to primary, 52 Up to secondary, 53 Secondary, 54 Post-secondary (as per record type (RT-110) of Cost of cultivation Scheme
Family size (FS)	Number of people in household
Land size (LS)	Land used for rice production (ha)
Occupation of the household head (OCU)	Dummy variable, 1 for agriculture, 0 for otherwise
Seed type (ST)	Dummy variable for seed type, 1 for HYV seeds used and 0 for otherwise
Irrigation machine (IM)	Dummy variable, if the farmers have their own irrigation machine, 1 and for otherwise, 0

Tobit Model analysis: To identify the factors that influence farm TE, AE and CE in the production of rice in the state, Tobit model was used. It is customary to regress the DEA efficiency scores on the relevant control variables (Fethi *et al.*, 2000; Hwang and Oh, 2008). Since the dependent variable, efficiency is a censored variable with a upper limit of one (Lockheed *et al.*, 1981), it is pertinent to use the Tobit model, which is a censored regression model, applicable in cases where the dependent variable is constrained in some way. The Tobit model may be defined as:

$$Y = \begin{Bmatrix} y^*; 0 \le y^* \le 1 \\ 0; \quad y^* < 0; \\ 1; \quad 1 < y^* \end{Bmatrix}$$

$$y^* = \beta x_i + e_i$$

Where,

y is the DEA efficiency score; $e \sim N(0,\sigma^2)$

y^* is a latent (unobservable) variable;

β is the vector of unknown parameters which determines the relationship between the independent variable and the latent variable;

x_i is the vector of explanatory variables.

Thus, the Tobit model used in this investigation may be specified as:

$$Y^* = \beta + b1AG + \beta_2 ED + \beta_3 FS + \beta_4 LS + \beta_5 OCU + \beta_6 ST + \beta_7 IM + e_i$$

Where,

y^* is the dependent variable (TE, AE and CE of rice farm)

The variables selected for use in this investigation for assessment of effects on efficiency are presented in Table 1.

The data from cost of cultivation scheme for the block period 2008-09 to 2010-11 was analyzed using DEAP version 2.0 described by Coelli (1996). Tobit model was estimated using EViews 9.0 software.

RESULTS AND DISCUSSION

Summary statistics for measures of technical, allocative and cost efficiency of different groups of farmers are presented in Table 2.

Table 2: Summary statistics of TE, AE and CE of rice growers

Category of farmers	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Marginal farmers			
Mean	0.680	0.582	0.396
Standard deviation	0.217	0.209	0.168
Minimum	0.258	0.085	0.082
Maximum	1.00	1.00	1.00
Small farmers			
Mean	0.666	0.598	0.398
Standard deviation	0.188	0.195	0.163
Minimum	0.295	0.113	0.107
Maximum	1.00	1.00	1.00
Medium farmers			
Mean	0.694	0.634	0.440
Standard deviation	0.205	0.202	0.194
Minimum	0.230	0.163	0.157
Maximum	1.00	1.00	1.00
Large farmers			
Mean	0.784	0.571	0.448
Standard deviation	0.189	0.205	0.207
Minimum	0.413	0.257	0.125
Maximum	1.00	1.00	1.00

Overall			
Mean	0.623	0.623	0.388
Standard deviation	0.191	0.197	0.164
Minimum	0.203	0.083	0.079
Maximum	1.00	1.00	1.00

The TE for marginal, small, medium and large farmers were estimated to be 68%, 66%, 69% and 78%, respectively and for overall, it was found to be 62% which implies that the output per farm of marginal, small, medium and large farmers may be increased by 32%, 34%, 31% and 22% through proper use of available technology and for overall farmers by 38%. The mean AE for all these four categories of farmers were computed to be 58% (marginal), 59% (small), 63% (medium) and 57% (large) which suggests that these farmers may be able to reduce their costs by 42%, 41%, 37% and 43%, respectively by considering appropriate input combinations along with relative input prices. Whereas for the farmers for the state as a whole, it (AE) was observed 62% this means they may reduce the input cost by 38% through manipulating the right combinations of input quantities and relative prices of inputs. The cost efficiencies of the different groups under study was calculated as marginal and small (40%), medium (44%) and large (45%). This means, as per Farrell's principle, these groups of farmers may potentially reduce their overall cost of rice production, on an average, marginal and small by 60%, medium farmers by 56 and large farmer by 55% in order to produce a given level of output at least cost using a given technology. In case of overall farmers for Bihar, CE was recorded 38.8% indicating that they may get the existing level of output by reducing the cost by 61.20%. i.e., to produce at least cost.

Table 3 shows the frequency distribution of farm-specific technical, allocative and cost efficiency for different categories of rice growing farmers of the state. Among marginal category, 36% of farmers operate between 40-60%, followed by 32% between 80-100% technical efficiency levels, while allocative efficiency was highest for 34% farmers in 60-80%, followed by 27% between 20-40% efficiency levels. In case of CE, the highest efficiency levels were observed between 20-40% for 58% cultivators, followed by 40-60% efficiency level for 36% rice cultivators. A close look of the investigation revealed that only 5% of the farmers operated their rice farms at optimal level. Maximum number of small farms recorded comparatively higher AE & TE level between 60-80% and 40-60% (efficiency level) respectively. Only 4.93% of the small farmers obtained the optimal level of output i.e., between 80-100% cost efficiency levels.

Table 3: Frequency distribution of efficiency scores

Category of farmers/ Efficiency intervals	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Marginal farmers (100)	**Frequency (number of farms)**		
10-20	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
20-40	8.00 (8.00)	27.00 (27.00)	58.00 (58.00)
40-60	36.00 (36.00)	23.00 (23.00)	36.00 (36.00)
60-80	24.00 (24.00)	34.00 (34.00)	1.00 (1.00)
80-100	32.00 (32.00)	16.00 (16.00)	5.00 (5.00)
Small farmers (203)	**Frequency (number of farms)**		
10-20	0 00 (0.00)	3.00 (1.48)	12.00 (5.91)
20-40	10.00 (4.93)	36.00 (17.73)	117.00 (57.64)
40-60	69.00 (33.99)	58.00 (28.57)	57.00 (28.08)
60-80	77.00 (37.93)	74.00 (36.45)	7.00 (3.45)
80-100	47.00 (23.15)	32.00 (15.76)	10.00 (4.93)
Medium farmers (100)	**Frequency (number of farms)**		
10-20	0.00 (0.00)	1.00 (1.00)	9.00 (9.00)
20-40	6.00 (6.00)	11.00 (11.00)	43.00 (43.00)
40-60	29.00 (29.00)	30.00 (30.00)	32.00 (32.00)
60-80	31.00 (31.00)	34.00 (34.00)	7.00 (7.00)
80-100	34.00 (34.00)	27.00 (27.00)	9.00 (9.00)
Large farmers (27)	**Frequency (number of farms)**		
10-20	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
20-40	0.00 (0.00)	4.00 (14.81)	10.00 (37.04)
40-60	5.00 (18.52)	10.00 (37.04)	14.00 (51.58)
60-80	9.00 (33.33)	9.00 (33.33)	1.00 (3.70)
80-100	13.00 (48.15)	4.00 (14.81)	2.00 (7.41)
Overall farmers (430)	**Frequency (number of farms)**		
10-20	0.00 (0.00)	3.00 (0.70)	35.00 (8.14)
20-40	53.00 (12.33)	73.00 (16.98)	245.00 (56.98)
40-60	173.00 (40.23)	113.000 (26.28)	114.00 (26.51)
60-80	113.00 (26.28)	149.00 (34.65)	17.00 (3.95)
80-100	91.00 (21.16)	92.000 (21.40)	19.00 (4.42)

Figures in brackets indicate percentage value

The technical efficiencies were found maximum between 80-100% for 34%, followed by 31% rice farms in the range of 60-80% in case of medium farmers. Majority of farmers of medium category (43%) could be able to harvest cost efficiency in the range of 20-40% level.

Further, perusal of the table revealed that among large category of farmers, as much as 48% farms could estimate the TE in the range of 80-100% and allocative efficiency was recorded (37.04% of the farmers) in the efficiency level 40-60%. The percentage of optimal level of output was recorded very poor i.e. only 7.41% of the large category farmers could produce at the optimal level with the existing combination of technical and allocative efficiency.

When overall scenario of the state was critically examined, the technical efficiency in rice production of maximum percentage of farmers (40.23%) fell in the range of 40-60% level and with regard to allocative efficiency, the maximum percentage of farmers (34.65%) were found to lie in between 60-80% efficiency level. A large proportion of the farmers as much as 56.98% were placed in the range of 20-40% of cost efficiency level. The fact as above indicates that only 4.42% of cultivators harnessed optimum level of output, thus it clearly reveals that majority of farmers may be considered as inefficient from the point of view of getting optimal level of output. To maximize the farm income from paddy cultivation, farmers have to shift from traditional farming to technical efficient farming along with the use of relative price oriented inputs to account for the maximum level of cost efficiency that is cost efficient farming.

The results of Tobit analysis are presented in Table 4. Age of the farmer showed negative and significant relation with technical efficiency. The reason for this may be that the older people engaged in faming works is not aware of technical knowhow or they are following traditional system of farming. The farmers or his family members, who are educated, prefer another job. Actually younger generations are migrating towards cities in search of jobs in non-agricultural sectors. Although the allocative efficiency indicated positive relation with age but combined effect i.e., cost efficiency revealed negative relationship resulting in less output i.e., cost efficiency declined with the increase in age of cultivators. Education of farmers exerted positive impact on technical efficiency, though it was insignificant. It clearly infers that more educated farmers are likely to be more technically sound as compared to less educated farmers.

Table 4: Estimation of the effects farm-specific variables on rice farming efficiency (Tobit model)

Variables	Technical efficiency (TE)	Allocative efficiency (AE)	Cost efficiency (CE)
Constant	0.5218*** (0.1885)	0.8720*** (0.1943)	0.4629*** (0.1614)
Age	-0.0013* (0.0007)	0.00018 (0.0008)	-0.00050 (0.00063)
Education	0.0046 (0.0034)	-0.0038 (0.0035)	0.0003 (0.0029)
Family size	0.0033 (0.00315)	-0.0006 (0.0033)	0.00355 (0.0027)
Irrigation machinery status	0.0032 (0.0199)	-0.0176 (0.0206)	-0.0151 (0.01708)
Household head occupation	-0.0741*** (0.0275)	-0.0701** (0.0284)	-0.1007*** (0.0236)
Paddy area	-0.0457* (0.0242)	0.0034 (0.0249)	-0.0077 (0.0208)
Seed	-0.0522 (0.0346)	0.0879** (0.0356)	0.0128 (0.0296)
Log likelihood	110.587	97.537	177.200

****, ** and * indicate significant at 1%, 5% and 10% level. Standard errors are given in brackets*

This finding pinpointed the fact that educated youths have to come forward and adopt faming as profession. Government and non-government institutions have to duly frame such policy that may lure younger and educated generation towards agriculture. Irrigation status of farmers explained the fact that the farmers owning the irrigation machinery are somewhat aware of technical importance of farming, even though most of them in state often use diesel pump sets for irrigation, which is costly and thus exerted negative association with allocative and economic efficiencies. The coefficient of household head occupation was observed be negative and significant with respect to all the three efficiencies i.e., TE, AE and CE. The negative association asserts that farmers are compelled to perform farming works because of non-availability of alternatives for other works. Poor economic status, lack of education and changing climatic scenario adversely affect their farming and thus, get less output with more inputs.

The coefficient of area under paddy cultivation was found to be negatively and significantly associated with the TE. This indicated that due to fragmented farms and limited resources, farmers are facing difficulties in cultivating the fragments lands at different places with the same level of technical efficiency, the other reason may be the financial conditions of the farmers. The variety of seeds used by the farmer also exerted negative relation with TE; the low seed replacement (39.13%) in the state may be one of the reasons for this. However, the variety of seed showed positive and significant relation with AE. Family size showed positive relation with TE and CE but it was negative with AE and these coefficients were found insignificant for all the three efficiencies.

CONCLUSION

Production efficiency is a vital component of production growth, particularly, in the state or nation whose economy is based on agriculture. The result of the study pointed out that overall TE and AE of sample farms were 62%. Further, the degree of overall production efficiency was estimated to be only 38.8%. Despite TE and AE being 62%, famers are still inefficient to achieve the optimal level of output. The study also suggests that a given level of output can be produced at least cost i.e. 61.2% cost may be reduced. Even in case of medium and large farmers, most of the farms accounting for 34% and 48.15%, respectively were laying in between 80-100 percent of technical efficiency group but on the other hand, only a few farms i.e. 9% medium and 7.41% large farms registered the cost efficiency level between 80-100% levels.

The Tobit analysis showed that younger generation had tempted to engage themselves in other than agricultural works. The farmers engaged in farming were less educated and consequently, had low level of technical knowhow. The quality of seed was needed to be taken care of. The cultivators were also unaware of relative prices of inputs. The inputs costs incurred more is resulting in less profitable enterprise. The irrigation based on diesel operated pump set was found costly. Technical knowhow regarding the core factors of production such as seeds, irrigation and knowledge of right combination and relative prices of inputs are lacking among the cultivators of the state. The farmers cultivating larger area under paddy are resource poor. The farms are fragmented and located at distant places, where they are unable to manage evenly all the fragmented farms. Finally, it may be concluded that the government and other policy maker should come forward and put sincere effort to make agriculture profitable, which may, in turn, attract the educated youth towards agriculture to opt as profession. Assured supply of good quality seed, irrigation facilities, dissemination of new farming technologies, better educational system and financial assistance, good marketing infrastructures should be ensured so as to make agriculture sector profitable, this may further enable the farming community to feed the teeming million of population and thus, reducing the poverty from rural areas of the state in particular and nation in general.

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