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Analysis of Scale Efficiency of Paddy Farmers in Bihar State: A Non Parametric Approach

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***Abstract**: The concept of farm efficiency has important implications for size productivity relationship and the extent to which farms have adopted the current technology. Using plot level input –output data on cultivation of paddy crop of a set of farmers in Bihar, the study ascertain the nature of scale efficiency among three different agro climatic zones of the state. Estimation was carried out by using Non-Parametric DEA. Empirical findings indicate a considerable difference of scale efficient farms among the three agro climatic zones in Bihar. The incidence of scale efficient farm is much higher among the marginal and small farmers compared to larger ones.*
***Keywords**: Scale Efficiency, Data Envelopment Analysis, Paddy cultivator.*

I. Introduction

Paddy is the major food grain consumed in most of the Indian states and plays a major role in Indian Economy. In Bihar this crop is cultivated in all districts. The state has about 3.2 million hectare under rice cultivation, which is mostly rain fed covering both upland and shallow lowland ecosystems. Although, the state is endowed with appropriate climatic conditions for the cultivation of rice, the cultivated area has decreased from 3.66 to 3.22 million hectare during the last six years. In order to meet the increasing demand of rice the concept of scale efficiency might be used to study the impact of scale economies on productive performance of farms. Therefore, it is interesting to observe how close an observed farm is to the optimal scale. For this, the present study undertakes the measure of scale efficiency in respect of farm size. The scale efficiency is a measure inherently relating to the return to scale of a technology at any specific point of the production process (Forsund and Hgalmarsson [1]). It describes the maximally attainable output for that input mix (Frisch [2]).

Under traditional agriculture, inputs used by various categories of farms are largely homogeneous. Moreover, knowledge about traditional technology is wide-spread among the farmers. As a consequence, scale diseconomies occur when net area rises behind a certain level. As a result productivity declines as farm size increases. However, with the advent of new technology, it is the large farms which enjoy the benefits of advanced technical knowhow. This has been possible due to the fact that some inputs which are endorsed by the new technology (such as improved seeds, fertilizers etc.) are rather non expensive in the case of big farmers. On the other hand small farmers cannot afford such inputs due to their very economic position. Moreover, knowledge about the new technology is yet to be wide-spread. As a consequence, it is the large farms which can go for technical improvement for raising productivity of land while small farmers lag behind. However, several studies have felt that there are certain aspects of new technology (such as efficient use of water resources, proper selection of crop mix, etc.) that might benefit the small farmers (Khan [3]; Carter [4]; Chattopadhyay et. al. [5] [6]). However, the picture might be altered substantially if a process of "catch-up" is in operation (Dyer [7])[1]. According to this process, small farmers might eventually gain access to new technologies, particularly tube-well irrigation, HYV seeds and chemical fertilizers therefore re-establishing the inverse relation between farm size and efficiency. This point was also raised by Berry and Cline [8], Bhalla [9]. The concept of scale efficiency can now be used in studying the productive efficiencies of different categories of farms separately for the agro climatic zones of Bihar to examine the catching up effect of land productivity.

The entire study is divided into five sections. The brief descriptions of data set used in this study are provided into section 2. In section 3, the study provides the methodology regarding estimates of scale efficiency using data Envelopment Analysis. Section 4 describes the empirical observations. The last section presents the conclusions of the study.

II. Data Description

The study is based on secondary data which were collected by the Directorate of Economics and Statistics in the Ministry of Agriculture [10] (DESMOA), Government of India. The DESMOA operates a scheme entitled Comprehensive Scheme for Studying Cost of Cultivation (CSSCC) of Principal Crops. The

[1] The term "catching up effect" has been used by Dyer (1998). It implies that the small farmers may eventually gain access to the modern technology even though they cannot benefit from it initially.

scheme was launched in the year 1970-71. It was meant to collect representative data on inputs and output in physical and monetary terms which could then be used for estimation of cost of cultivation per hectare and cost of production per quintal of principal crops. The data under this scheme was collected on a continuous basis in the form of a detailed survey in respect of principal crops to be covered for one year which was to be subsequently studied on a sub-sample. The sampling design proposed for the collection of representative data was one of three stage stratified random sampling wherein the tehsils formed the first stage sampling units, a cluster of villages as the second stage sampling units and an operational holding within a cluster as the third and ultimate stage sampling unit. The holdings were then selected randomly from each of the size class for collecting detailed input output data. The present study was used farm-level disaggregated data pertaining to the year 2010-11 for paddy crops in Bihar. For this state the CSSCC authority selects 382 sample farmers covering 48 numbers of villages from 25 districts for collection of data. CSSCC categories the entire state into five agro climatic zones. However, this study undertakes the classification undertaken by Government of Bihar ([11]. Table 1 describe the topographical features of the three agro climatic Zones.

Table: 1 Agro Climatic Zones in Bihar

Zones	Districts	Soil	Ph	Total rainfall (mm)	Temperature (Degree Celsius)	
					Max	Min
Zone-1 (North west alluvial plane)	Saran, Siwan,E.Champaran, W. Champaran, Sitamarhi, Madhubani, Darbhanga, Muzzafarpur, Vaishali, Samastipur, Begusarai	Sandy loam, loam	6.5 – 8.4	1040 – 1450 (1245.00)	36.6	7.7
Zone-2 (North-East Alluvial Plane)	Supaul, Saharsa, Madhepura, Purnea, Katihar	Sandy loam, Clay Loam	6.5 – 7.8	1200 – 1700 (1450.00)	33.8	8.8
Zone-3 (South Alluvial Plane)	Munger Rohtas, Aurangabad, Buxar, Bhojpur, Gaya, Nalanda, Patna, Nawada	Sandy loam, Clay loam, loam, Clay	6.8 – 8.0	990 – 1240 (1115.00)	37.1	7.8

Source: Ministry of agriculture, Government of Bihar

The data consisted of information on agricultural production and means of production in the sample state. cultivator wise record of output, human labour hour, machine labour hour, Crop area, Seed value, Fertiliser cost, Manure cost, insecticides, irrigation cost were obtained. Specification of output and inputs in the analysis was as follow:

Output: production of paddy crop measured in terms of quintal
Inputs: (i) Human Labour hour (ii) Machine labour hour (iii) Material input cost.
Human labour hour consist (a) Family Labour hours (b) Attached labour hours and (c) Casual labour hour. Machine labour hour consist (a) Hired machine hours and (b) Owned machine hours. Material input cost consist cost of (a) Seed (b) fertilizer (c) manure (d) Insecticides (e) Own Irrigation machine and (f) hired Irrigation Machines. All the input and output variables are measures in per unit of area.

III. Methodology

The concept of scale efficiency was introduced by Lovell and sickles [12] and later elaborated by Fare, Grosskopf and Lovell [13]. Scale efficiency measures the efficiency of the scale of operation. Suppose that a firm enjoyed increasing return to scale so that it is possible to sustain a large output vector given the input vector. However, if the observed output vector is unduly small so that there still remains enough scope for furthering output, the firm is scale inefficient. Similarly, scale inefficiency occurs if the produced output is unduly high while decreasing returns to scale is in operation. Scale efficiency is measured by comparing efficiency scores under Constant Return to Scale (CRS) and Variable Return to Scale (VRS) under a Data Envelopment Analysis (DEA) framework. Fare, Grosskopf and Lovell [13] defined scale efficiency as follows:

$$S(y_i, x_{ij}) = \frac{E_i^{CRS}}{E_i^{VRS}} \qquad (1)$$

Where, S can be termed as scale efficiency, measured for farms producing output y_i using inputs x_{ij} (j stands for input-specific subscript).
E_i is the input saving efficiency measure based on frontier technology and is given as

$$E_i = \min_{\propto_i}\{\propto_1 : (F_1(Y, \propto_1, X) \leq 0\} \qquad (2)$$

The DEA approach to measure efficiency from the envelope is to

$\max_{E_i,\lambda} E_i$, (3)

Subject to $y_i \leq \lambda Y; \lambda X \leq E_i X_i; \lambda \geq 0$

Where X is a n × I input matrix with column x_i, Y is a m × I output matrix with column y_i, λ is a I × 1 intensity vector and I is the number of farms in a particular set of observations. Problem (3) has been solved for I time to get each producer's efficiency score which is being evaluated under different sets of observations as envelope. Regarding frontier technology, the most common restrictions are strong disposability of input and output and convexity of the set of feasible input-output combinations. One can assume three types of return to scale viz., (i) Constant Return to Scale (CRS) (ii) Non Increasing Return to Scale (NIRS) (iii) Variable Return to Scale (VRS). These returns to scale assumptions impose certain restrictions on the intensity vector λ. Under the CRS assumption, λ is unrestricted. NIRS is incorporated within a DEA structure by adding to equation 3 the constraint $e^T \lambda \leq 1$ where e is a $I \times 1$ vector of ones. Similarly, VRS might be specified by adding to equation 2 the constraint$e^T = 1$. Following this one can get efficiency scores for each of the individual farm under CRS and VRS specification. Finally, by putting the values of E_i under CRS and VRS in equation (1), the scale efficiency of the farm was obtained. Färe, Grosskopf and Lovell (1994) posited certain properties for $SE(y_i, x_{ij})$. First, it lies between zero and unity. Again, it is homogeneous of degree zero in inputs. Finally, it is independent of the unit of measurement.

IV. Results And Discussion

Ideally one can treat farms with efficiency score equal to unity ($S_i = 1$) as efficient while those less than one as inefficient. However, since the study has not taken into account the effect of random events because of the DEA structure used in this analysis, it is highly possible that some farms with lesser efficiency scores are also efficient in the sense that they have been unable to attain unitary efficiency due to some technical constraints like natural holocausts, machine or equipment failures, product defects etc. which are outside their control. Hence it would be safe to treat farms with efficiency scores greater than 0.8 ($S_i > 0.8$) as efficient and other as inefficient. The Zone wise frequency distribution of farmers according to their levels of efficiency, derived fromS_i, is presented in table 2.

Table 2: Frequency distribution of farming households by level of scale efficiency

Levels of Scale Efficiency (%)	Number of Farms			
	Zone-1	Zone-2	Zone-3	All
Upto 0.50	22 (11.64)	1 (1.67)	2 (1.50)	25 (6.54)
0.51-0.60	10 (5.29)	3 (5.00)	4 (3.01)	17 (4.45)
0.61-0.70	20 (10.58)	11 (18.33)	37 (27.82)	68 (17.80)
0.71-0.80	41 (21.69)	8 (13.33)	9 (6.77)	58 (15.18)
0.81-0.90	50 (26.46)	25 (41.67)	20 (15.04)	95 (24.87)
0.91-1.00	46 (24.34)	12 (20.00)	61 (45.86)	119 (31.15)
All	189 (100.00)	60 (100.00)	133 (100.00)	382 (100.00)

Notes: Figures in parenthesis indicates Percentages

Table 2 shows a considerable difference of levels of efficiency among the farmers between three zones at Bihar. For zone -1 (i.e., North-west Alluvial Plane), the percentage of scale efficient farmers ($S_i > 0.8$) is 50.80%. Whereas, in Zone-2 (North-east Alluvial Plane) and zone-3 (South Alluvial Plane) the percentage of scale efficient farmers are 61.67% and 60.90% respectively. For Bihar as a whole the figure is 56.00%. Therefore, the incidence of scale efficient farmers is lower in the North-west alluvial plane in Bihar. Presumably, better availability of irrigation and other infrastructural facilities have helped the farmers of Zone 2 and zone 3 to intensify their cultivation for better productivity. For zone 1 the type of interventions needed to be putted for enhancing the productivity of paddy farming.

However, distribution of efficient farms by size-classes of holdings across the three different agro-climatic zones gives somewhat different results (Table 3). Table 3 shows that majority of marginal and small farmers belong to the efficient category for all the three zones of Bihar. The result is also true for Bihar as a whole. In fact, it is observed from the table that as farm size increases, the incidence of efficient farmers decreases. This is true for all the three zone as well as Bihar as a whole.

Table 3: Size Distribution of Scale Efficient farms

	Percentage of Efficient Farms			
	Zone-1	Zone-2	Zone-3	All
Marginal (0-1Ha.)	47 (48.45)	14 (37.84)	38 (44.70)	99 (45.21)
Small (1-2 Ha.)	30 (30.93)	13 (35.14)	22 (25.88)	65 (29.68)
Semi medium (2-4 Ha.)	19 (19.59)	10 (27.08)	17 (20.00)	46 (21.00)
Medium (4-10 Ha.)	1 (1.03)	0	8 (9.41)	9 (4.11)
Large (10-above Ha.)	0	0	0	0
All	97 (100.00)	37 (100)	85 (100)	219 (100)

Following Sen (1982), we may also compare the percentile of efficient farms against each size-class of holdings. This is presented in table 4. From this table we observed that so far as the Zone-1 is concerned, while 55.81 percent of the marginal farmers are efficient, this is as high as 75 percent for the medium size group. However, for small and medium farmers the percentages of efficient farms are 49.18 and 50.00 respectively. This means that there is no systematic relationship between farm size and preponderance of efficient farms with in a particular size. When we consider other zones or all the zones together, there appears to be no significant differences in the distribution of efficient farms across different size-groups of holdings.

Table 4: Percentage distribution of farms by efficiency and inefficiency in each size group of holdings

	Percentage of Total Farms in each size Group of Holdings							
	Zone-1		Zone-2		Zone-3		All	
	Eff.	Ineff.	Eff.	Ineff.	Eff.	Ineff.	Eff.	Ineff.
Marginal	55.81	44.19	70.00	30.00	69.81	30.19	62.26	37.74
Small	49.18	50.82	72.22	27.78	60.00	40.00	56.14	43.86
Semi Medium	50.00	50.00	55.56	44.44	51.52	48.48	51.69	48.31
Medium	75.00	25.00	0.00	100.00	66.67	33.33	55.00	45.00
Large	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALL	52.91	47.09	61.67	38.33	62.41	37.59	57.59	42.41

Hence, there appears to be an apparent contradiction between the percentage distribution of efficient farms among the different size classes of holdings as indicated in table 3 and the percentile of efficient farms against each size-class of holdings as presented in table 4. In this context, we can compare the incidence of efficient farms in terms of some index (suggested by Sen, [14]) for each size- class of holdings and for each zones of Bihar. Index of efficiency scores are presented in table 5. Where,

$$\text{Index} = \frac{\text{Percentage of efficient farms among the different size class of holdings (Table 3)}}{\text{Percentage of efficient farms against each size class of holdings (Table 4)}}$$

Table 5 shows that the incidence of efficient farms is much higher among the small farmers compared to the larger ones for all the zones as well as Bihar as a whole. In fact, judging by the indices it is clear that the incidence of Marginal farm efficiency is much more pronounced in the zone-1 of Bihar compared to the other two zones. A possible explanation for this phenomenon may be provided below.

Table 5: Index of Scale Efficiency

Size Groups	Zone-1	Zone-2	Zone-3	All
Marginal	0.87	0.54	0.64	0.73
small	0.63	0.49	0.43	0.53
Semi Medium	0.39	0.49	0.39	0.41
Medium	0.01		0.14	0.07
Large	0	0	0	0

Marginal farmers try to obtain maximum yield from their small piece of land mainly for their survival. There is a certain basic minimum of consumption that a small peasant family has to have without which it will simply be wiped out. He therefore, gives intensive effort to produce maximum output on his piece of land by small scale irrigation and other such means that can be procured with the help of labour. All these efforts help the marginal farmers to appear more productive than the medium and large farmers. In fact, many authors e.g., Hanumanta rao [15], Bhagwati and Chakravorty [16], Chattopadhyay and Rudra [17] have made similar observations.

V. Conclusions

The concept of scale efficiency has important implications for size productivity relationship and the extent to which farms have adopted the current technology. In this context, the present study concerned about pattern of scale efficiency. Using farm level data on crop production of a set of farmers in the state of Bihar, the study have tried to ascertain the nature of scale efficiency using non-parametric DEA. The results indicate that the majority of small and marginal farmers in all the three zones as well as in Bihar as a whole are found to be efficient. However, further studies using different data sets and alternative methodologies are required before one can come to firm conclusions in this regard.

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