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Micro aspects of farmer's performance using data envelopment analysis: A study based on West Bengal

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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 farm level input output data on paddy cultivation of a set of farmers in West Bengal, we have tried to ascertain the pattern of efficiency. The study reveals that there is an over-utilisation of available resources as well as considerable scope for expanding output in West Bengal agriculture. The paper also deals with the efficiency differential among different categories of farmers in respect of agro-climatic zone in West Bengal.
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The farm-size productivity debate was originally initiated by Sen (1962, 1964). The arguments advanced in this debate, so far, are however highly unsatisfactory. Firstly, the analysis was not carried out properly for different types of crops as well as all crops taken together (Dyar, 1998; Sharma and Sharma 2000; Sengupta and Kundu, 2006). The large farmers tend to diversify in order to alleviate risks involved in agrarian production. Small farmers with their limited resource ability concentrate only on a few crops. As such comparison between these two types of farmers should involved in inter crop variation. Secondly, the distinction between the so called advanced and backward zones is not rigorous (Dyer, 1998). It appears that these distinctions are made on subjective basis with some a priori assumptions. Thirdly, the very basis of the debate is questionable. As argued by Lee and Somwaru (1993), land productivity and input intensity are valid measures of relative efficiency only under very restrictive assumptions such as constant return to scale. They suggest the use of efficiency as an ideal parameter in this regard. The simple productivity analysis using yield per hectare and farm size may not be sufficient to understand the pattern of farm efficiency. This is because efficiency depends on a number of factors that could not be captured by yield per hectare alone (e.g., productivity of other inputs besides land, level of technology used, etc., may be incorporated in the analysis). The present study deals with all these issues in the context of some new data set that is being available from rural India.

Materials and Methods

The farmers in underdeveloped areas exhibit wide differences in their resource use pattern. It thus seems interesting to study efficiency differentials among farmers of different categories. West Bengal is one of the states in India where large-scale land reforms have resulted in breaking up of vested interests in land holding pattern to a certain extent (Dyer, 1998). Several authors have argued that such measures have contributed to significant efficiency gain (Banarjee *et al.* 2002). It thus remains imperative to examine the extent to which these gains have been translated in production economies. However, since this is a micro level analysis, it is difficult to include policy variables directly. Their effects can only be gauged indirectly.

The data used in this exercise were collected by the Ministry of Agriculture, Government of West Bengal through the Cost of Cultivation Scheme. We have used in this study farm-level disaggregate data pertaining to the years 2009-10 for west Bengal state only. This data set supplies information on various inputs like human labour, bullock labour, fertilizer, manure, machine and output of all the crops cultivated both in value and quantitative terms. For our efficiency estimates we have taken only three inputs namely human labour hour, bullock hour and fertilizer that presumably explain production of most of the crops very well. All these variables are measured in per unit area..

In West Bengal, the entire state was divided into six agro climatic zones on cultivation practices, type of soil, irrigation facilities and rainfall, namely : (1) Hilly Zone; (II) Teri Zone (III) Old Alluvial Zone: (IV) New Alluvial Zone: (V) Coastal Saline Zone and (VI) Red Literate Zone. A single zone may contain blocks belonging to different districts. There exist wide differences in cultivation practices, topographic features and climatic conditions across these zones. We have divided these zones broadly into two sub-groups: alluvial zone and non-alluvial zone. The alluvial zone includes zones III, IV and V (Old alluvial, New alluvial and Coastal saline) while the non alluvial zone includes zones I,II, and VI (Hilly zone, Terai and Red laterite). The alluvial zone with its typical soil topography, cultivation practices, irrigation facilities and pattern of rainfall may be considered as advanced zone while the non alluvial zone may be considered as backward. In the region under study paddy is the main crop.

The present study was under taken to examine the relationship between farm-size and productivity as well as input use of the crop under study. For this we have fitted both linear and log-linear relationships showing output per acre against net cultivated area and input use per acre against net cultivated area. The effect of farm size on gross value productivity and input use was quantified by estimating the following regression equations.

Linear Regression Equations:

(i) $Y = A + BX$ (ii) $L_{h} = A + bX$

(iii) $L_b = A + bX$ (iv) $F_c = A + bX$

Log-Linear Regression Equations:

(i) $\text{Log}Y = A + b\,\text{Log}X$ (ii) $\text{Log}\, L_{h} = A + b\,\text{Log}X$

(iii) $\text{Log}L_b = A + b\,\text{Log}X$ (iv) $\text{Log}\, F_c = A + b\,\text{Log}X$

Where Y is gross value productivity of different variety crops per acre, X is farm size, L_h L_b F_c are the human labour hour, bullock labour hour and value of chemical fertilizer per acre respectively.

Next, we propose to study the performance of farmers using the framework of Data Envelopment Analysis (DEA). The linear programming technique is applied to estimate the values of the parameter E_i that capture the degree of efficiency Now, Farrell's (1957) measure of efficiency based on frontier technology is defined as follows:

$$\max_{E_f \lambda} E_f \quad \text{subject to} : y_f \le Y\lambda \,,\; X\lambda \le E_f x_f \quad \ldots\ldots (1)$$

The imposition of constraint on the intensity vector λ guarantees that E_i lies between zero and one. The problem (1) assumes CRS. Banker, Charnes and Cooper (1984) have relaxed this assumption. Their model is essentially same as that of the above but relaxing CRS everywhere. In this context, Fäare, Grosskopf and Lovell (1994) have defined **scale efficiency** as:

$$SE\,(y_i, x_j) = \frac{E_i^{CCR}}{E_i^{BCC}} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where E_i gives efficiency score for the i th farm respectively under CRS and VRS specifications. SE can be termed as scale efficiency, measured for farms producing y_i output-using inputs x_j (j stands for the input-specific subscript). Fäare, Grosskopf and Lovell (1994) posited certain properties for $SE\,(y_i, x_j)$. 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. Scale efficiency measures the efficiency of the scale of operation. Suppose that a farm enjoys 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 expanding output, the farm is scale efficient. Similarly, scale inefficiency occurs if the produced output is unduly high while decreasing returns to scale is in operation.

Since it had been a common contention that the apparent inverse relationship between farm size and productivity is largely due to scale diseconomies, the concept of scale efficiency might be used to study the impact of scale economies on productive performances of farms. Under traditional agriculture, inputs used by various categories of farms are largely homogeneous. Moreover, knowledge about traditional technology is widespread among the farmers. As a consequence scale diseconomies occur when net area cultivated rises beyond a certain level. As a result productivity declines as farm size increases. However, with the advent of new agricultural technology, it is the large farms that enjoy the benefits of advanced technical know how. This has been possible due to the fact that some inputs that are endorsed by the new technology (such as improved seeds, fertilizers, etc.) can be afforded mostly by the large farmers. Moreover, knowledge about the new technology is yet to be widespread. As a consequence, it is the large farms that can go for technical improvement for rising productivity of land while small farmers lag behind.

However the picture might be altered substantially if a process of "Catch up" is in operation (Dyer, 1998). According to this process, small farmers might eventually gain "access to new technologies, particularly tubewell irrigation, high-yielding variety (HYV) seeds and chemical fertilizer thereby re-establishing the inverse relation" (Dyer, 1998; Berry and Cline, 1979; Bhalla, 1979).

Higher scale efficiency indicates better use of the available technology. Full-scale efficiency is achieved when its value is unity. Scale inefficiency may be due to untapped increasing returns to scale or overuse of the available scale. The former is a measure of unrealized possibility often mitigated due to lack of adequate resources that make operation at a fuller scale economically viable. The later is an indicator of misuse of resources that could have been better diverted to alternative uses. The nonparametric DEA methodology provides techniques in identifying the two alternative cases.

Results and Discussion

We first examine the farm size on productivity relationship using both linear and log-linear regression. The results of regression analysis are shown in Table 1.

The results (Table 1) of regression analysis indicate for non alluvial zone, the coefficient is significantly positive. Thus the study supports the view that the inverse farm size productivity relationship has disappear for non alluvial zone in West Bengal. For alluvial zone it has reappeared. All these seems to give an indication that the size productivity relationship may perhaps be negative although for various constraints and limitations with the data, it is not possible to conclude strongly whether the relation is indeed at the village level in statistical sense. Next we present the input use pattern of the farmers in Table 2.

Table 1: Farm Size and Productivity Relationship

	Linear			Log linear		
Zone	Slope	Correlation Coefficient (R^2)	t df(n-2)	Slope	Correlation Coefficient (R^2)	t df(n-2)
Alluvial	-281.93	0.020	-1.943	-0.029	0.008	-1.222
Non Alluvial	321.815	0.081	4.554**	0.080	0.085	4.686**
West Bengal	131.144	0.006	1.648	0.058	0.035	3.908**

** implies significant at 1% level

Table 2. Farm Size and Input Use Relationship

	Input	Alluvial Zone			Non-Alluvial Zone			West Bengal		
Linear		Slope	R^2	t value	Slope	R^2	t value	Slope	R^2	t value
	HL	-6.65	0.028	-2.35*	-4.62	0.027	-2.56*	-5.32	0.026	-3.39**
	BL	-1.39	0.023	-2.09*	-2.79	0.088	-4.77**	-2.33	0.061	-5.28**
	FR	-13.75	0.008	-1.26	15.32	0.027	2.58*	7.80	0.004	1.23
Log Linear	HL	-0.05	0.046	-3.01**	-0.08	0.027	-2.57*	-0.04	0.032	-3.77**
	BL	-0.13	0.014	-1.63	-0.26	0.046	-3.37**	-0.19	0.035	-3.94**
	FR	0.04	0.005	0.95	0.07	0.023	2.353*	0.09	0.025	3.32**

* implies significant at 5% level
** implies significant at 1% level

Table 3. Frequency distribution of technical efficiency

	Alluvial Zone			Non-Alluvial Zone			West Bengal		
	CCR	BCC	Scale	CCR	BCC	Scale	CCR	BCC	Scale
0-0.1	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
0.1-0.2	1 (0.52)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (0.93)	0 (0.00)	0 (0.00)
0.2-0.3	12 (6.28)	0 (0.00)	0 (0.00)	6 (2.52)	0 (0.00)	1 (0.42)	52 (12.12)	0 (0.00)	5 (1.17)
0.3-0.4	49 (25.65)	1 (0.52)	3 (1.57)	13 (5.46)	0 (0.00)	4 (1.68)	102 (23.78)	5 (1.17)	17 (3.96)
0.4-0.5	54 (28.27)	28 (14.66)	14 (7.33)	38 (15.97)	4 (1.68)	7 (2.94)	122 (28.44)	54 (12.59)	19 (4.43)
0.5-0.6	24 (12.57)	39 (20.42)	30 (15.71)	55 (23.11)	23 (9.66)	15 (6.30)	55 (12.82)	92 (21.44)	62 (14.45)
0.6-0.7	15 (7.85)	23 (12.04)	38 (19.89)	44 (18.49)	45 (18.91)	19 (7.98)	27 (6.29)	92 (21.44)	105 (24.48)
0.7-0.8	11 (5.76)	32 (16.75)	38 (19.89)	30 (12.61)	53 (22.27)	43 (18.07)	22 (5.13)	88 (20.51)	80 (18.65)
0.8-0.9	9 (4.71)	31 (16.23)	32 (16.75)	28 (11.76)	59 (24.79)	74 (31.09)	16 (3.73)	49 (11.42)	64 (14.92)
0.9-<1	8 (4.19)	17 (8.90)	26 (13.61)	15 (6.30)	32 (13.45)	65 (27.31)	16 (3.73)	26 (6.06)	62 (14.45)
1.00	8 (4.19)	20 (10.47)	10 (5.24)	9 (3.78)	22 (9.24)	10 (4.20)	13 (3.03)	23 (5.36)	15 (3.50)
Total	191 (100)	191 (100)	191 (100)	238 (100)	238 (100)	238 (100)	429 (100)	429 (100)	429 (100)

Note: The figures in brackets indicates percentage

Among the inputs, family labour bears a negative relation to farm size for both advance as well as backward zone. Loss of job opportunities elsewhere might be a plausible reason for this tendency. Bullock labour also bears a negative relation to farm size for both the zone. Fertilizer cost bears a negative relation to farm size for alluvial zone. However, for non alluvial zone there is a significant positive relation for this input. This might be a direct fall-out of the rising cost of the substitutable input fertilizer in the reform period. A possible explanation might be sought in the rising relative price of this item after withdrawal of subsidies to a certain extent.

The process of globalization has moved the marginal farmers to a precarious level while benefiting the larger groups. The benefits are undoubtedly asymmetric. However land productivity and input intensity are valid measures of relative efficiency only under very restrictive assumptions such as constant returns to scale (Lee and Somwaru, 1993). They suggest the use of efficiency as an ideal parameter in this regard. The simple productivity analysis using yield per hectare and farm size might not be sufficient to understand the pattern of farm efficiency. This is because efficiency depends on a number of factors that could not be captured by yield per hectare alone (e.g., productivity of other inputs besides land, level of technology used etc. may be incorporated in the analysis) (Dyer, 1998). This is our task in the next section.

The efficiency scores pertaining to BCC and CCR methods as well as that of the scale efficiency are presented in table 3 and 4. It is interesting to note that there are some common features in the efficiency pattern of different crops. For all the efficiency measures, the average scale efficiency is much larger than the Banker, Charnes and Cooper (BCC) or Charnes Cooper and Rhodes (CCR) models [Charnes *et al.* (1978, 1979, and 1981)]. Given that the standard deviations are of comparable levels, it implies that, on an average, the farmers are able to exploit scale economies to a certain extent. However, the distribution of scale efficiency indicates a negative skewness for alluvial, non- alluvial as well as West Bengal as a whole. As for Zone specific features, it appears that apparently the distribution of efficiency appears to be more symmetric when we consider the BCC and CRR models for alluvial Zone in comparison to non-alluvial zone. However, the mean efficiency for non alluvial zone is rather high. However, even for non-alluvial zone, scale efficiency shows a strong negative bias. Hence it becomes difficult for us to sustain the "catching up" effect for West Bengal Agriculture.

Next, we turn to the use of slack and surplus variables. Slack variable represents amounts of excessive input use. They reveal the extent to which use of a particular input be reduced given that a farm has already reached the frontier of the production set. In contrast, surplus variables reveal how much a farm on the production frontier could further increase its output without consuming additional units. The analysis of slack variables from CRR model (similarly for BCC model), for example, suggest that on an average there is a considerable scope for reducing the current input use.

Table 4: Summary Statistics of the Efficiency Measures

	Alluvial Zone			Non-Alluvial Zone			West Bengal		
	CCR	BCC	scale	CCR	BCC	scale	CCR	BCC	Scale
Mean	0.52	0.71	0.73	0.64	0.78	0.81	0.49	0.68	0.72
Standard deviation	0.20	0.18	0.17	0.18	0.14	0.16	0.20	0.16	0.17
Median	0.47	0.71	0.72	0.62	0.79	0.84	0.44	0.67	0.70
Kurtosis	0.021	-1.23	-0.77	-0.64	-0.74	1.03	0.50	-0.67	-0.44
Skewness	0.097	0.095	-0.04	0.16	-0.21	-1.11	1.09	0.26	-0.20
Range	0.82	0.62	0.68	0.77	0.57	0.70	0.82	0.64	0.73
Minimum	0.18	0.38	0.32	0.23	0.43	0.30	0.18	0.36	0.27
Total	191	191	238	238	238	238	429	429	429

Table 5: Analysis of Slack and Surplus Variables.

Input/output	No. of farms with zero slack/ surplus		Slack/surplus as a proportion of total (input/output)		Number of farmers
	CCR	BCC	CCR	BCC	
Alluvial Zone					
Labour	8	13	-0.4933	-0.2953	191
Bullock	7	13	-0.5408	-0.3348	191
Fertiliser	7	12	-0.4918	-0.2987	191
Output	8	13	+0.0012	+0.2178	191
Non Alluvial Zone					
Labour	5	9	-0.3673	-0.2222	238
Bullock	4	8	-0.6416	-0.3267	238
Fertiliser	4	7	-0.3670	-0.2351	238
Output	5	9	+0.0001	+0.0065	238
West Bengal					
Labour	7	10	-0.5099	-0.3223	429
Bullock	6	9	-0.5441	-0.3469	429
Fertiliser	7	9	-0.5141	-0.3257	429
Output	7	10	+0.0001	+0.1121	429

The problem appears for all the zones under consideration. However it is quite severe for alluvial zone than non alluvial zone if we consider Human labour and fertilizer. Whereas the problem is quite severe for use of bullock labour of we consider alluvial zone. The number of farms with zero slack is relatively high for alluvial zone. A farm is efficient only if it has zero slacks and E_i =1. There may be observations with Ei =1 but non zero slacks. Such farms are not efficient. This may imply that farmers are better acquainted in alluvial zone. Input wise analysis reveals that the extent of over utilisation is more sever for Bullock Labour than for labour and fertiliser. In contrast, surplus variables reveal how much a farm on the production frontier could further increase its output without consuming additional units.

Thus for alluvial zone, under BCC, output can increase roughly around 21% of the current level and for West Bengal as a whole possible output increase is roughly 11%. However, for Non-alluvial Zone the result is less dramatic, indicating less than 1% increase of the current output level. Thus efficient reorientation of output may result a change in cropping pattern itself.

Conclusion

In this paper we are concerned about the input utilisation pattern of the farmers in West Bengal. The concept of scale efficiency has important implications for size productivity relationship and the extent to which farms have adopted the current technology. Our analysis reveals over-utilisation of the available resources as well as considerable scope for expanding output. The farm size and productivity relationship indicate a negative relation for alluvial zone in rural Bengal.

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