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MEASUREMENT OF FARM LEVEL ECONOMIC EFFICIENCY AN APPROACH TO UNIT COST OF PRODUCTION

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Abstract

A methodology is developed for measurement of farm level *overall productive efficiency* in terms of unit cost of production on application of *three sigma rule* to reduce the gap between theory and practice in this regard. The study analyses unit cost of production to examine resource use patterns and farm efficiency across different size groups of farms in paddy production in West Bengal based on farm level primary and secondary data. It appears that the bottom class (i.e., below 1 acre) is least efficient, whereas top size class (i.e., 4 acre and above) is most efficient. Minimization of unit cost is very important for the farmers for augmentation of their economic efficiency and profitability and for the sake of sustainability of the farming system. There is a scope of reduction of unit cost in West Bengal agriculture and also for the country as a whole.

Key words: Farm size, Economic Efficiency, Unit Cost.

JEL Classification : C1, Q12

Introduction

The term efficiency is generally used in production economics for measuring relative performance of different production units. It requires a standard or norm either in terms of output, or cost or profit to facilitate comparison with other farm so far as efficiency is concerned. Measurement of efficiency is very important for enhancement of growth of output and optimum utilisation of resources, to identify the existing gap between farm's actual performance and its potential level of performance and to distinguish between efficient farms and inefficient farms. It has great policy implications also. In the literature of the subject there are two important modern frontier measures of efficiency: (i) Stochastic frontier production function analysis (SFA) – stochastic approach, (ii) Data Envelopment Analysis (DEA) - deterministic approach. The present study develops a measure of farm level productive efficiency in terms of unit cost of production on application of *three sigma rule* significantly based on the conceptual framework of the great work of Farrell (1957). This paper tries to bridge the gap between

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theoretical novelty and empirical reality regarding frontier measurement of productive efficiency. On the basis of primary survey an applicability of this unit cost analysis method is examined in HYV Boro paddy production in Nadia district of West Bengal. Cost function for paddy production is estimated to examine the state of agriculture in West Bengal and for the country as a whole based on secondary data collected from Study on Farm Management and Cost of Production of Principal Crops in West Bengal and Rural Development statistics 2011-12, NIRD. The rest of the paper is organised as follows: Section I deals with conceptual framework, Section II estimates cost functions for paddy production during 2005-06, and Section III analyses primary data and estimates efficiency scores on the basis of unit cost analysis method discussed in Section I.

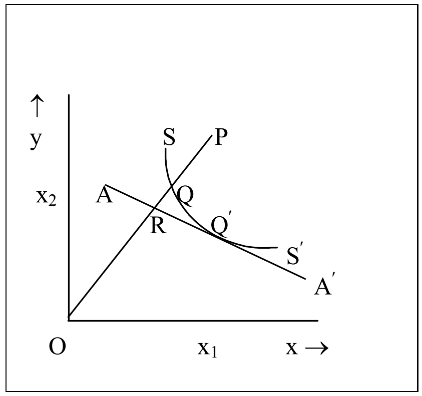
1. Theoretical Framework

Measures of Efficiency

The great works of Debreu (1951), Koopmans (1951) and Farrell (1957) are very important contributions to the theoretical literature on measurement of efficiency. Debreu has introduced a coefficient of resource utilization yielding measures of the efficiency of the economy based on vector–set properties in the commodity space. According to him the loss associated with a non-optimal situation is a measure of the distance from the actually available complex of resources to the set of optimal complexes. T.C. Koopmans has theorised efficient allocation of resources in production by employing two basic concepts: the commodity and the activity. According to him the concept of productive efficiency is: "An attainable set of commodity flows, as well as any set of activity levels giving rise to it, is called *efficient* if there is no other attainable set of commodity flows in which all flows are at least as large as the corresponding flows in the original set, while at least one is actually larger."

Farrell has given a systematic and satisfactory measure of productive efficiency which takes account of all inputs and which has shown how it can be computed in practice with an illustrative example related to agriculture in the United States. One of the most important features of his study (Figure 1) is the distinction between *'price efficiency'* (OR/OQ) and *'technical efficiency'*(OQ/OP). The former measures a firm's success in choosing an optimal set of inputs, the latter its success in producing maximum output from a given set of inputs. According to him, under conditions of constant returns to scale the product of the technical and price efficiencies is called *'overall efficiency'* (OR/OP =OQ/OP* OR/OQ) of the inefficient firm represented by the point P.

Figure 1



(reproduced from Farrell, 1957)

Debreu and Farrell defined productive efficiency in relative terms. This is popularly known as radial measure in efficiency literature. Koopmans defined it in absolute term. Modern efficiency measures and its refinements at both theoretical and empirical levels begin with the concepts developed by Farrell. But the terminology 'economic efficiency' instead of 'overall efficiency' and 'allocative efficiency' instead of 'price efficiency' is to be found most often in recent literature. This paper develops a methodology for measurement of overall productive efficiency in terms of unit cost of production on application of three sigma rule which is significantly based on the conceptual framework of the great work of Farrell and uses it to measure farm level economic efficiency in paddy production in West Bengal.

The performance of the production unit is often judged by utilising the concept of economic efficiency (EE). The EE is defined as the capacity of a production unit to produce a predetermined quantity of output at minimum cost for a given level of technology. The EE can be further decomposed as has been done (overall efficiency = technical efficiency X price efficiency) by Farrell (1957) into technical efficiency (TE) and allocative efficiency (AE). By TE, we mean the ability of a production unit to produce maximum possible output (i.e., to produce on a frontier isoquant) with the help of a given input mix and a technology. Thus, technical inefficiency arises when actual or observed output is less than the frontier output. Allocative efficiency refers to the ability and willingness of a production unit to produce a given level of output with minimum input cost. Efficiency in allocation of resources (or inputs) requires appropriate combination of factors.

These concepts of efficiency can be demonstrated graphically (Figure 2) with two inputs X_1 and X_2 and single output Y in terms of cost and output measures.

From the point of view of cost

$$\text{Economic Efficiency } (EE_{Cost}) = \frac{\text{Standard Cost}}{\text{Actual Cost}}$$

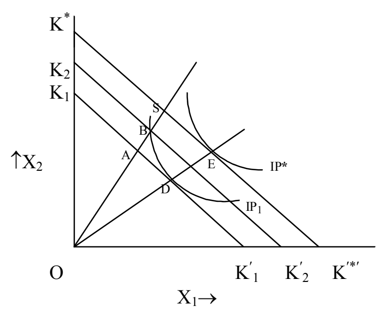
If for any observation, $EE_{Cost} < 1$, the sample is cost-inefficient.

From the point of view of output.

$$\text{Economic Efficiency } (EE_{Output}) = \frac{\text{Actual Output}}{\text{Standard Output}}$$

If for any observation, $EE_{Output} < 1$, the sample is output – inefficient.

Figure 2



(reproduced from Nandi, 2012)

Suppose the isoquant IP_1 in Figure 2 represents production frontier for Y (i.e., maximum possible efficient output) with the given resource base. The lowest isocost line K_1K_1 is tangent to this isoquant at point D. Thus, point D is both technically and allocatively efficient because it remains on the production frontier and also satisfies the condition of equality between the ratio of marginal products and relative prices.

Let S be an observed point of an inefficient unit with output indicated by IP_1 iso-product curve. Thus, S (which is on the iso-cost line $K^*K^{*/}$) indicates much higher resource requirements for the same amount of output. This means, observed cost for the production unit represented by point S is both technically and allocatively inefficient.

For the output indicated by IP_1 the Optimum or Economically Efficient point is D. So for S

(the observed point)

$$\text{Economic Efficiency } (EE_{Cost}) = \frac{OA}{OS} < 1$$

Obviously, S is an inefficient point compared with B (a technically efficient point being on IP_1) where OB may be taken as measure of standard cost, for S

$$\text{Technical Efficiency } (TE_{Cost}) = \frac{OB}{OS} \text{ (which is also less than 1)}$$

Therefore, the distance BS represents the technical inefficiency of the unit operating at point S. In other words, it can reduce its input costs to the extent of the distance BS with the given technology to achieve the frontier production. Generally, efficiency/inefficiency is measured in terms of proportion (or percentage). Thus, technical inefficiency of the concerned unit of production is defined as BS/OS and its technical efficiency is equal to one minus BS/OS which is equal to OB/OS.

But when B (which is on a higher iso-cost curve) is compared with D (the optimum point on the same iso-product curve but at a lower iso-cost line), the allocative efficiency may be measured in terms of factor proportion as follows:

$$\text{Allocative Efficiency } (AE_{Cost}) = \frac{OA}{OB} < 1,$$

where OA is the measure of standard cost.

The distance AB represents allocative inefficiency of the unit since A is a point on the isocost line $K_1K'_1$. In this case also, there is a possibility of cost reduction by the production unit to the extent of AB. Thus, allocative inefficiency of the unit can be defined as AB/OB and one minus this ratio is equal to OA/OB that measure allocative efficiency.

Thus,

$$\text{Economic Efficiency } (EE_{cost}) = \frac{OA}{OS} = \frac{OB}{OS} (TE) \times \frac{OA}{OB} (AE)$$

Therefore, economic efficiency is the resultant of allocative and technical efficiency. The economic inefficiency for the production unit operating at point S is then represented by the distance BS plus AB (=AS). In other words, inefficient unit at S to be an efficient one if it could reduce it costs to the extent of AS. Thus, economic inefficiency is defined as AS/OS (= 1-OA/OS, where OA/OS is the economic efficiency).

Figure 2 in addition to depicting cost efficiency in terms of Farrell also helps us to measure efficiency in terms of output as well. From the point of view of output, economic efficiency of observed point S may be measured as follows. For the iso-cost line $K^*K^{*/}$ on which S is located, E is the optimum or economically efficient point being the point of tangency of the relevant iso-cost line and the iso-product curve. From the point of view of output, for the incurred cost at S, the optimum output is OE (E being a point on IP^*) but the actual or observed output is OD (D being a point on IP_1). Therefore,

$$\text{Economic Efficiency } (EE_{output}) = \frac{OD}{OE} < 1$$

Obviously, S is an inefficient point.

Now, the crucial problem is then to estimate efficient isoquant SS′ in Figure 1 or IP_1 in Figure 2 (i.e., determination of norm or standard) from observations of the inputs and outputs of a number of sample farms. The way of determination of such norm or standard is not only very critical and complex but also very controversial in the literature of the subject. There are two basic approaches to the measurement of efficiency- one is deterministic approach and another is the stochastic approach. In both approaches, we have found basically two types of analysis for taking into consideration the norm or standard in measuring efficiency. First type of analysis is based on the concept of average as standard while the second is relatively modern and it is popularly known as frontier analysis where maximum in case of output or minimum in case of cost is used as the basis (or standard) for comparison.

For a long time the average productivity of labour is considered as the measure of efficiency. But it is not a satisfactory measure as it ignores all other inputs. Several attempts have also been made to consider all inputs to construct “indices of efficiency” in which a weighted average of inputs is compared with output. In case of deterministic model with cross section data, an average index is generally formed for all production units under consideration and the relative efficiency of each unit is calculated in relation to this average index. Obviously, some units perform better than average and some other unit lie below it. But these attempts have suffered from usual index number problems (Farrell, 1957, pp.-253).

A wide range of methodologies (Charnes, Cooper and Rhodes 1978, Meeusen and Van den Broeck 1977, Aigner, Lovell and Schmidt 1977, and Battese and Corra, 1977, Battese and Coelli 1988, Greene1990) have already been developed in the literature of the subject both at micro and macro levels. Data Envelopment Analysis-DEA (deterministic) and Stochastic Frontier Production Function Analysis-SFA (stochastic) are two important and commonly used in modern efficiency measures that are represented by some form of frontier function. DEA method involves the use of linear programming to construct a non-parametric piece-wise frontier by connecting points of 'best practices' units over the data and relative performances of different units are judged compared with this frontier envelope. On the other hand, the economic logic behind the development of stochastic frontier production function ($Y_i = f(X_i, \beta)$ exp. (ε_i), where, $\varepsilon_i = v_i - u_i$) is that the disturbance term (ε_i) is decomposed into two economically distinguishable random disturbances with different characteristics. First part of the disturbance (v_i) is pure white noise and the second part (u_i) reflects technical and economic inefficiency. Such a distinction greatly facilitates the estimation and interpretation of a frontier. The productive efficiency can then be measured by the ratio between actual output and the estimated maximum output obtained from the application of maximum likelihood method (MLE) on the stochastic frontier production function. Research on examination of the relative strengths of these two important modern efficiency measures (i.e., DEA and SFA) has also been continued, particularly after 1990's. Randall Campbell, Kevin Rogers and Jon Rezek have tried to develop an alternative efficiency estimation approach utilising generalised maximum entropy (GME) that combines the strengths of both SFA and DEA. In their analysis of study, they have used 3σ rule as the two-sided error (random disturbance) support points.

For determining the standard (in terms of cost/output) we use the three sigma rule on unit cost of production as follows:. The three sigma rule states that the probability for a random variable (X), with mean μ and variance σ^2 and with uni-modal Lebesgue density falling away from its mean by more than 3σ is at most 5 per cent,

$$\Pr(|X - \mu| \geq 3\sigma) \leq 4/81 < 0.05 \quad \text{(Pukelsheim, 1994).}$$

For normal distribution mean $\pm$ 3σ include about 99 per cent of the observations. For cost which has to be minimised, the standard may be taken as (mean-3σ); and for output/profit which has to be maximised the standard may be taken as (mean +3σ).

For primary data, a standard average cost (c^*) may be first determined.

For any observation i(i = 1,2,3….n), unit cost (c_i) may be defi

$$c_i = \frac{C_i}{Q_i}$$

Where, C_i= Total cost[1] and Q_i = output

Standard Deviation (S.D) has to be estimated on the basis of $c_{1,}\ c_{2,} \ldots.. c_n$

So, Standard average Cost (c^*) = Mean of c_i's – 3 S.D of c_i's

Thus for the i^{th} observation from the point of view of cost

$$\text{Economic Efficiency } (EE_{cost})_i = \frac{c^*}{c_i}$$

Thus, the relative performance (efficiency) of a farm or a unit of production can be judged with respect to unit cost of production (which includes all inputs) and a standard value (yard stick) of the concerned variable. After calculation of unit of production and the standard value of unit cost of production, the efficiency of one farm may be compared with that of each of the peer group. In this connection, it is worth mentioning that Farrell has opined that it is far better to compare performances with the best actually achieved than with some unattainable idea (Farrell, 1957, pp. 225). Our rule suggests that the performance of a particular farm be evaluated in comparison with the best achieved among 99 per cent (95 per cent) of the peer farms.

In this method, there is no need to construct or assume a virtual farm (as in case of DEA method) or assume any distributional functional form of efficiency/ inefficiency component (as in case of SFA). If our primary objective is to judge the relative performance of a farm in relation to its peer group, then this method may be useful on the ground that it is easy to understand and easy to calculate without the help of sophisticated computer programming. It is also easy to interpret and more realistic. Furthermore, extreme possibilities are being excluded in this method (DEA method is very sensitive to extreme cases).

II. Estimation of Cost Function

From the decomposition of unit cost we have the following conditions:

$$\text{since unit cost } (c) = \frac{\text{Total cost (C)}}{\text{Total output (Q)}} \quad ,:$$

(1) c will decrease, when increase in C < increase in Q

i.e., under condition of Increasing Returns to Scale (IRS).

(2) c remains constant, if increase in C = increase in Q

i.e., under condition of Constant Returns to Scale (CRS).

(3) c will increase, when increase in C > increase in Q

i.e., under condition of Decreasing Returns to Scale (DRS).

Therefore, output elasticity of total cost determines the state of the farmers in production. Running following regression one can do this.

$$\text{Log } C = \alpha + \beta \text{ Log } Q + \gamma \text{ Log } S$$

where S includes shift factors such as farm size, input prices, input structure, level of technology, time etc in the cost function $C = f(Q,S)$.

Thus, β denotes output elasticity of cost and is equal to

$$= (dC/dQ).(Q/C) = (dC/dQ)/(C/Q) = MC/AC$$

Now if $\beta > 1$. It will indicate $MC/AC > 1$ or $MC > AC$, which implies DRS.

Similarly, $\beta = 1$ implies CRS and $\beta < 1$ implies IRS. Thus, β is a very crucial parameter and is most often use to measure economies of scale.

Estimated cost functions based on secondary data are shown below:

Estimated cost function in Aman and Boro paddy (HYV): West Bengal

$$\text{Log } C = 7.541^{*} + 0.650^{*} \log Q - 0.023 \text{ FSc} + 0.305^{*} D$$

(t-value) (19.50) (6.08) (-1.25) (6.88)

R-squared = 0.842^{*}, Adj R-squared = 0.829, F (3,38) = 67.44

No. of obs. = 42 (across farm sizes: 2005-06),

Estimated cost function in Total Paddy: All India

$$\text{Log } C = 7.097^{*} + 0.820^{*} \log Q - 0.087^{**} \text{ FS}$$

(t-value) (23.36) (9.48) (-1.77)

R-squared = 0.886^{*}, Adj R-squared = 0.867, F (2,12) = 46.6

No. of obs. = 15 (across States: 2005-06).

From the analysis of regression results it is observed that:

(i) The coefficient of Q (output elasticity of cost) is significantly less than one in both models which implies that there is increasing returns to scale in paddy production in

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Note: * indicates significant at 1 % level. ** = indicates significant at 10 % level. C= cost (Rs.) per hectare, Q= Output (Qtl.) per hectare, FS = Average size of Holdings (hectare), FSc = Farm size code defined as: Marginal (1), Small (2), Medium (3), & Big (4), D= dummy variable defined as: Aman(HYV) =0 and Boro (HYV) = 1.

West Bengal and for the country as a whole. Thus, there is a scope of reduction in unit cost of production in agriculture which is very important from the view point of both consumers (lower unit price) as well as producers (higher profitability).

(ii) Cost of production is inversely related with farm size. Reasons may be the greater economies of scale and higher bargaining power enjoyed by the big farmers.

(iii) Positive and significant dummy coefficient of 0.305 implies the fact that cost of production per hectare in Boro (HYV) is significantly higher than that of in Aman (HYV) production in West Bengal.

Further, from the analysis of Farm Management Survey data we observed that:

(i) A significant portion of total cost in paddy production is found to be labour cost (Aman (HYV) - Boro: 40.57%-31.75%) followed by cost of chemical fertiliser (6.59%-8.59%) and cost of irrigation (1.32%-16.75%) during 2005-06 in West Bengal (see Appendix 1).

(ii) Out of 15 major States under consideration, Punjab (Rank 1) is observed to be least unit cost of Rs. 487.28 per quintal paddy production in 2005-06 and Jharkhand ranked 15th with unit cost of Rs. 751.95. The position of West Bengal is the 10th with unit cost of Rs. 581.02 (see Appendix 2).

III. Analysis of Primary Data

Following the prescription in the Methods of Farm Management Investigation, FAO, Agricultural paper No. 80, 1965 (W.Y.Yang) we have total 112 sample farm households (selected through the process of simple random sampling with replacement) out of 571 households spread over Majhergram (Gangsara Mouza) under Majhergram Gram Panchayat in the block Ranaghat-II of Nadia district (one of the advanced districts in respect of agriculture) in West Bengal for our study. Out of total 112 sample farms we have found that 83 (largest in number) farms have been producing Boro (HYV) paddy in the study area. The proportion of area of Boro paddy in total cropped area is also higher than the rest of the crops grown in the study area. Boro (HYV) paddy is the main crop, in the sample village, accounting for 30.66 per cent of total cropped area followed by Aman (26.16), Jute (15.24), Aus (8.27), Mustard (7.27) and Wheat (6.38). Besides these crops, sample farms also grow vegetables, fruits (particularly banana) and flowers (specially marigold). Cropping intensity in the study area is found to be 270 per cent. Farmers depend mainly on minor irrigation system of (Shallow and Deep) Tubewells with both electric and diesel pump sets.

For the district as a whole, the share of Boro (HYV) paddy area is also highest among the principal crops grown in Nadia. Thus, we now proceed to analyse resource use pattern and farm efficiency in Boro (HYV) paddy cultivation for these 83 farms.

The analysis is based on two main classifications: First, size class of operational land holdings viz. Below 1 acre (34 farms) and 1-2 acre (24 farms), 2-4 acre (20 farms) and 4 acre & above (5 farms); and second, the occupational classes such as (a) pure cultivation (47 farms), (b) cultivation plus business (18 farms) and (c) cultivation plus services (18 farms). It may be noted that shop keeping and vending are the main types of business. The main types of services are village level teaching and medical practices (alternative system of medicines).

The following facts have also emerged in course of interviews with the farmers in the sample area:

1. There has been no soil testing during last about 15 years. Most of the farmers have got necessary information about the dose of fertiliser, insecticides from the suppliers (local traders) of inputs. Sample farmers sometimes use salt in Boro (HYV) production to get immediate favourable impact on production but such practice may significantly reduce the fertility of the soil in near future and increase further salinity of the soil.
2. In respect of diversification, floriculture may be suitable in the study area but high volatility in the prices of flowers entails high risk to the farmers. Fruits, vegetables, flowers are grown in nearby plots of land around farmhouses. Longer the distance from the farmhouse, less is the cropping intensity (CI).
3. Extension services particularly in respect of farm practices are not available in the area.
4. High cost of irrigation due to increase in electricity charges.
5. There is a tendency of leasing in/out for a single crop on either crop sharing or fixed rent basis. Smaller farms partly leased in land to absorb his family labour in production of crops, whereas land may be leased out mainly because of two types of constraints: (i) dearth of family level supervisory man power, and sometimes also (ii) dearth of resources to meet cost of cultivation. Landholders generally lease out temporarily to their close relatives, neighbours or friends.

To examine resource use efficiency in Boro (HYV) cultivation we use the method of analysis of unit cost of production discussed above. In this method we first calculate average cost of production for all sample farms and then estimate a standard minimum average cost on application of 'three sigma rule' in which economic efficiency (EE) of the farms are measured. The results are summarised in the subsequent Tables.

TABLE 1

Mean and dispersion of Efficiency Score and some other related variables in Boro (HYV) production.

	Mean	Maximum	Minimum	Coefficient of Variation (C.V.)
1. Economic Efficiency Score	0.687	0.911	0.564	0.11
2. Yield rate of Main Product (in quintal) per acre	20.43	21.6	16.8	0.06
3. Value of Output per rupee of total expenditure (Rs.)	1.39	1.88	1.09	0.12
4. Value of Output (Rs.) per Man Day	225	313	141	0.14
5. Percentage of Family Labour to Total Labour	37.35	91.67	3.85	0.52
6.Fertiliser Consumption (in k.g.) per acre	267	450	135	0.29
7. Paid out cost per quintal output (Rs.)	521	658	382	0.12
8. Price of Main Product (Rs.) per quintal	688	710	620	0.04
9. Net Farm Business Income (Rs.) per acre	5528	8670	2565	0.28
10. Farm Size (acre)	1.62	6.33	0.17	0.80
11. No. of Fragmentation per acre	3.81	6.92	1.33	0.36
12. Family Size (no.)	5.18	10	2	0.30
13. Age of Decision Making Farmers (yrs.)	44	72	25	0.21

Source: Field Survey.

It is observed that economic efficiency scores of sample farms in Boro (HYV) production varies from a minimum of 0.564 to a maximum of 0.911 with the value of standard deviation

0.076 (Table 1). On an average, efficiency score is estimated to be 0.687 which means farmers are efficient (overall) in Boro (HYV) production to the extent of 68.7 per cent. It implies that there is a scope of increase in production of this crop through proper use of the resources at their disposal in hand.

Average yield rate per acre is estimated to be 20.43 quintal with little variation of it among farmers (value of CV is about 6 per cent). Overall productivity defined as value of output per rupee of total expenditure (costs) ranges from 1.09 to 1.88 and with 1.39 average value of it. The variations in farm size, family size, number of fragmentation per acre, profit per acre, proportion of family labour in total labour and fertiliser use are found to be greater than those in respect of other variables.

Mean efficiency scores for different classification of farmers are shown in Table 2 and Table 3.

Table - 2 : Mean Efficiency Score as per size classes of farms.

Farm size by operational holdings (in acre)	Mean Score (EE)	Standard Deviation
Below 1 acre	0.667	0.06
1-2 acre	0.692	0.08
2-4 acre	0.685	0.08
4 acre and above	0.795	0.08
Total	0.687	0.08

Source: field survey

From the analysis of mean scores as per size classes of operational holdings of farms it appears that the bottom class (i.e., below 1 acre) is least efficient (about 67 per cent), whereas top size class (i.e., 4 acre and above) is most efficient (about 80 per cent). There is no significant differences in mean efficiency scores of two intermediaries' size classes of 1-2 acre and 2-4 acre both are efficient to the extent of about 69 per cent.

Table - 3 : Mean Efficiency Score as per Occupational classes.

	Mean Score (EE)	Standard Deviation
1. Pure Cultivator	0.676	0.08
2. Cultivator plus Business	0.688	0.07
3. Cultivator plus Service	0.711	0.06

Source: Field Survey.

It is observed from the analysis of Table 3 that farmers depending on pure cultivation are less efficient than the farmers who have other sources of income along with cultivation (like business and service) possibly due to inaccessibility on the part of pure cultivators to supporting resources particularly finance in such a high cost production of Boro(HYV) paddy.

Table - 4 : Determinants of Economic Efficiency: Rank Correlations (R)

Correlation coefficient between Economic Efficiency and	Value of R	Level of Significance
1. Farm Size (in acre)	0.25	5 per cent
2. Fertiliser Consumption (per acre)	-0.26	1 per cent
3. Asset Value other than Land (in Rs.)	0.30	1 per cent
4. Yield Rate (per acre)	0.34	1 per cent
5. Labour productivity (output per man day)	0.45	1 per cent
6. Distance of the plot of land from the residence of farmers.	-0.17	Not significant
7. Number of fragmentation per acre	-0.07	Not significant

Source: Field Survey.

It appears from the analysis of correlation coefficients given in Table 4 that economic efficiency tends to increase significantly with farm size. Compared to other varieties of crops generally grown in the district, expenditure required per acre is generally higher for Boro Paddy. The larger farms may be more equipped to incur appropriate levels of expenditure and they attain higher levels of efficiency vis-à-vis smaller farms. The rate of fertiliser use, the distance of the land from the residence and fragmentation have negative effect on efficiency, whereas such other factors as volume of non-land asset, yield rate and labour productivity have positive impact on economic efficiency in the study area. Level of education (higher education) and age of farmers (below 50 years) are also important factors influencing economic efficiency in crop production positively though not significantly in the study area.

The fact that the rate of chemical fertiliser use has negative effect on economic efficiency needs close scrutiny since it may be due to over-use of a high cost resource (in the absence of soil testing) which has to be often procured with borrowed funds.

It is true that minimisation of unit cost is very important for the farmers for augmentation of their economic efficiency and profitability and for the sake of sustainability of the farming system. We have found that farm business income (profit over paid out cost) and unit cost of production are significantly and inversely related; estimated correlation coefficient is –0.79.

We have now regressed unit cost of production on the yield rate per acre (YLD), rate of fertilizer use per acre (FERT) and farm size (FS).

The results are summarised below.

$$UC = 912.679 - 19.834\ YLD - 13.495\ FS + 0.334\ FERT$$

(t-value) (9.46) (-4.05) (-3.02) (4.29)

$R^2 = 0.325$, Adjusted $R^2 = 0.299$, $F(3/79) = 12.67$

It is observed from the regression results that the variation in unit cost among sample farms in Boro (HYV) production is significantly explained by the variations in yield rate, rate of use of fertiliser and farm size to the extent of about 33 per cent.

The multiple regression results endorse the indications obtained from correlation coefficient measures (Table 4): i) increase in farm size tends to lower unit cost and thus increase economic efficiency, and ii) increase in the rate of chemical fertiliser use tends to increase unit cost and thus reduce economic efficiency.

As farm size and yield rate increase, unit cost will decrease, but the higher rate of use of chemical fertiliser may increase unit cost of production and thus reduce farm business income. Increase in yield rate is not commensurate with increase in cost of chemical fertilizer. The policy prescription that logically emerges is that we have to minimise the use of chemical fertilizer (which represents high cost technology) and use low-cost plant nutrition like different kinds of organic manure in order to reduce unit cost without affecting yield rate.

Note:

1. As agriculture is characterized by joint production, the cost per unit of output (i.e., unit cost) of 'main product' is generally calculated based on subtraction of the value of 'by product' from the total cost of production. That is,

$$\text{Unit cost of main product} = \frac{\text{Total cost} - \text{Value of by product}}{\text{Total quantity of main product}}$$

Appendix - 1 : % of total cost under different items of expenditure in paddy production in West Bengal, 2005-06

Items of expenditure	Aus	Aman	Aman	Boro
	(H.Y.V)	(Local)	(H.Y.V)	
Human Labour				
Hired	25.51	21.62	26.70	20.23
Family	16.30	25.00	13.87	11.52
Seed	2.41	3.24	2.59	2.62
Manures	5.91	6.01	5.22	3.50
Fertilizers	7.00	1.12	6.59	8.59
Irrigation	3.41	---	1.32	16.75
Others	39.46	43.01	43.71	36.79
Total	100	100	100	100

Source: Directorate of Agriculture, Govt. of West Bengal

Appendix - 2 : Average yield and unit cost of production of Paddy across States in India , 2005-06

	States	Yield	**Rank**	Unit cost	**Rank**
		(Qtl./ha.)	**(Descending)**	(Rs./Qtl.)	**(Ascending)**
1	Andhra Pradesh	50.21	**2**	540.96	**6**
2	Assam	25.17	**13**	559.92	**9**
3	Bihar	25.78	**12**	497.44	**2**
4	Chattisgarh	27.27	**11**	508.21	**3**
5	Haryana	48.72	**4**	618.45	**11**
6	Jharkhand	14.41	**15**	751.95	**15**
7	Karnatka	49.11	**3**	518.54	**4**
8	Kerala	35.37	**7**	671.66	**12**
9	Madhya Pradesh	16.03	**14**	689.82	**13**
10	Orissa	30.24	**10**	528.90	**5**
11	Punjab	61.15	**1**	487.28	**1**
12	Tamil Nadu	42.92	**5**	690.96	**14**
13	Uttar Pradesh	34.37	**9**	559.19	**8**
14	Uttarakhand	34.95	**8**	552.97	**7**
15	West Bengal	37.18	**6**	581.02	**10**

Source: Same as in Appendix 1

References :

Aigner, D., Lovell, C.A.K.and Schmidt, P. (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics* 6(1), 21-37.

Battese, G.E. and Coelli, T.J. (1988), "Prediction of Firm-Level Technical Efficiencies: With a Generalised Frontier Production Function and Panel Data", *Journal of Econometrics*, 38, 387-399.

Battese, G.E. and Corra G.S. (1977), "Estimation of a Production Frontier Model: With Application to the Pastoral Zone Off Eastern Australia", *Australian Journal of Agricultural Economics* 21(3), 169-179.

Campbell, R.; Rogers, K. and Rezek, J., "Efficient Frontier Estimation: A Maximum Entropy Approach" Department of Finance and Economics Mississippi State University.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978), "Measuring the Efficiency of Decision Making Units', *European Journal of Operational Research,* 2, 429-444.

Debreu, G. (1951), "The Coefficient of Resource Utilization," *Econometrica* 19(3), 273-292.

Farrell, M.J. (1957), "The Measurement of Productive Efficiency", *Journal of the Royal Statistical Society,* Series A, General, Part 3, 253-281.

Government of West Bengal, Directorate of Agriculture: *Study on Farm Management and Cost of Production of Principal Crops in West Bengal, Vol. XLVIII, 2005-06 & 2006-07.*

Greene, W.H. (1990), "A Gamma-Distributed Stochastic Frontier Model", *Journal of Econometrics* 46(1/2), 141-164.

Koopmans, T.C.(1951), "An analysis of Production as an Efficient Combination of Activities", In T.C. Koopmans (ed.), *Activity Analysis of Production and Allocation,* Wiley.

Meeusen, W. and Van den Broeck, J. (1977), "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error", *International Economic Review,* Vol.18, No.2, June.

Nandi, A. K., (2012), *Resource use Patterns and Resource Use Efficiency in Crop Agriculture: An Approach to Frontier Analysis*, Lap Lambert Academic Publishing GmbH & Co. KG, Germany.

Pukelsheim, F. (1994), "The three sigma rule", *American Statistician*, Vol.48, No. 2, May, pp. 88-91.

Yang, W.Y. (1965), "Methods of Farm Management Investigation", *FAO Agricultural Paper* No. 80.