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TECHNICAL EFFICIENCY OF RICE PRODUCTION IN PONDICHERRY: A STOCHASTIC FRONTIER PRODUCTION FUNCTION MODEL

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ABSTRACT

The present study had been undertaken with the primary-data of cost of cultivation of paddy in Karaikal region, Pondicherry. The study was conducted with 60 farmers, which has a large area under paddy cultivation. Agriculture is the main occupation of this region. The reference period of the study was 2011. The analysis revealed that there is an under utilization of fertilizers, which indicated that fertilizers use has to be increased. The use of machine and bullock power should be rationalized to increase the yield. Resource use efficiency analysis implied that there was an ample scope to increase the production by proper technology and optimum allocation of resources. Efficiency of farmers can be supported by mean technical efficiency, the results of which indicated that there is scope for further improvement in the technical efficiency of farmers in the study area.

KEYWORDS: Resource Use Efficiency, Stochastic Frontier Production Function, Technical Efficiency, Returns To Scale

INTRODUCTION

Agriculture is the backbone of India’s economy, providing direct employment to about 70.0 per cent of working people in the country. Thus the progress of country’s economy depends to large extent on the performance of agriculture sector. At an aggregate level the output performance of agricultural sector in India appears to be quite impressive with a quantum of level of food production from a rock bottom of about 50.8 million tones during 1950 - 51 to 208.9 million tones in 2000-02. But Indian agriculture has to upgrade its capacity to provide an additional seven to nine million tones of food grains every year in order to meet the projected demand.

Among the crops grown, rice has historically been the single most important commodity in much of Asia for atleast three important reasons. First, rice supplies a large share of caloric intake in many countries, especially for the poor. Second, rice still accounts for an important share of total economic activity in the very poor countries. Thus, it is important not only for rice farmers but also in some instances for the macro economy. Third,
rice is a political commodity. Food riots will erupt if citizens perceive changes in prices to be too sharp or abrupt. Although the importance of rice is declining in all three of these respects, it will arguably remain the most important commodity in the region for some time to come.

World wide, India stands first in rice area and second in rice production, after China. It contributes 21.5 per cent of global rice production. Within the country, rice occupies one-quarter of the total cropped area, contributes about 52.0 per cent of total food grain production and continues to play a vital role in the national food and livelihood security system. Throughout the post independence era, unparallel developments have taken place as a result of the green revolution. A combination of increased area and greater cropping intensity transformed India from a net importing country in mid 1960s to a potential exporter of quality rice in early 1990s. The development and rapid adoption of high yielding rice varieties from late 1960s contributed to phenomenal output growth and enhanced per capita availability of rice, despite a doubling of the population. The total rice production in 2002 - 03 was about 72.7 million tones. However, India would need to produce at least 200 million tones of rice to meet its ever-growing population requirements and this figure would have to increase by almost 75.0 per cent by 2020. The future of food security in the country will depend on its ability to improve rice productivity continuously on an ecological basis (Subbiah et al., 2001).

Agriculture is the main occupation of the people of Karaikal region. In this region food crops cultivated in 14,322 hectares, which accounted for 95.7 per cent of the total cropped area of that region. Among the food crops cultivated Rice is one of the principal crops. 58.7 per cent of area is under rice to total cropped area in this region. (Season and crop report 2000 - 01, Pondicherry). The area under rice production in Karaikal region has decreased from 9180 ha in 1995 - 96 to 8533 ha in 1999 - 00. Since rice is water intensive crop and given the restricted availability of irrigation potential in this region, increasing the area under the crop is not feasible. Hence the increase in production would have to come from a breakthrough in productivity and increased efficiency in production. Hence shifting the farmers getting low yields to higher levels can increase the average yield level in the state. In order to achieve this, it is important to identify the various inputs, which directly or indirectly affect the farm output. Hence it is important to study the technical efficiency of rice. In the present study an attempt has been made to measure the farm level technical inefficiency which can be the dominant factor in explaining the difference between potential and observed yield of rice for a given technology and input levels.
Data and Methodology

The present study had been undertaken with the primary-data of cost of cultivation of rice in Karaikal region, Pondicherry. The total sample size is 60, which has a large area under rice cultivation. Agriculture is the main occupation of this region. The reference period of the study is 2011. In Karaikal region food crops were cultivated in 14,322 hectares, which accounted for 95.7 per cent of the total cropped area and nearly 58.7 per cent of area is under paddy cultivation. (Season and crop report 2000 - 2001). The Karaikal region receives rainfall from the Northeast monsoon benefiting the farmers in cultivation of paddy crop with an annual rainfall received of 961mm.

Technical Efficiency

Technical efficiency refers to the proper choice of production function among all those actively in use by farms in the agriculture. A farmer is said to be more technically efficient than another if he consistently produces larger quantities of output from the same quantities of measurable inputs. In the present study, an attempt was made to measure the production efficiency of paddy farms on the basis of the stochastic frontier production function.

Frontier Production Function

Frontier production function represents a maximum possible output for any given set of inputs making use of best technology available thus setting a limit or frontier on the observed values of dependent variable in the sense that no observed value of output is expected to lie above this frontier. Any deviation of a farm from the frontier indicates the extent of farms inability to produce maximum output from its given set of inputs and hence represents the degree of technical inefficiency. A production process may be inefficient in two ways, only one of which can be detected by an estimated production frontier. It can be technically inefficient in the sense that it fails to produce maximum output from a given input bundle. The other type of inefficiency could be allocative inefficiency in the sense that the marginal revenue product of input might not be equal to the marginal cost of that input even though the technology is efficient.

The estimation of production frontier has proceeded along the two general paths. Deterministic frontier - which forces all observation to be on or below the production frontier so that all the deviations from the frontier are attributed to inefficiency and other representing the usual random noise. The advantage of deterministic frontier is the farm - specific efficiency and random error can be separated. The key feature of the stochastic production
frontier is that the disturbance term is composed of two parts; one, symmetric and the other one sided. The symmetric component captures the random effects outside the control of the decision-maker including the stochastically noise contained in every empirical relationship (such as poor input performance, bad weather, input supply breakdown etc.) the one sided component captures deviations from the frontier due to inefficiency.

Stochastic Frontier

The following equation denotes the production frontier in the matrix form

\[ Q_i = Q(Xk_i, \beta)e^{\Sigma_i} \]

\[ i = 1, 2, \ldots, n \quad k = 1, 2, \ldots, k \]

Where \( Q_i \) is the output of the \( i^{th} \) farm, \( x_i \) is the vector of \( K \) inputs of the \( i^{th} \) farm. \( \beta \) is the vector of parameters to be estimated and \( \Sigma_i \) a farm specific error terms. The stochastic frontier is called a ‘composed’ model because the error term is composed of two independent elements, namely

\[ \Sigma_i = V_i - U_i \quad , \quad i = 1, 2, \ldots, n \]

The term \( v_i \) is the symmetric component and permits random variation in output due to factors like weather and plant diseases. It is assumed to be identically and independently distributed as \( V_i \approx N(O, \sigma^2 V) \). A one sided component \( (U_i \geq 0) \) reflects technical efficiency relative to the stochastic frontier \( Q_i = Q(X_{u_i}, \beta)e^{v_i} \). Thus \( v_i = 0 \) for any farm lying on the frontier, while \( u_i > 0 \) for any farm lying below the frontier. Hence, expression \( u_i \) represents the amount by which the frontier exceeds realized output. Assuming that \( u_i \) is identically and independently distributed as \( U_i = (0, \sigma^2 u) \), that is the distribution of \( u \) is half–normal. Thus \( u_i \) takes the value zero when the farms produce on its outer–bound production function (realizing all technical efficiency potential) and is less than zero when the farm produces below its outer bound production function (not realizing fully its technical efficiency potential). This might happen due to a number of factors, such as risk aversion, self–satisfaction, information problems, which may prevent the farm from achieving its fully potential. Density function can be written as

\[ f_{U_i}(U_i) = \frac{1}{\sigma U \sqrt{1/2\pi}} \left[ -1 \right]^{U_i} \left[ \frac{-1}{2U_i^2 \sigma^2 U} \right] \text{if } U_i \geq 0 \]
Its follows that \( \sigma^2 = V(\sum \sigma)^2 = \sigma^2V + \sigma^2U \)

Further defining \( \lambda = \frac{\sigma U}{\sigma V} \) i.e. ratio of one-sided error term to symmetric error term.

The Cobb-Douglas functional form is generally preferred in most published papers on technical efficiency because of its well-known advantages. Its purpose is to show what output of a given product will be achieved by different combination of factors. However, it is possible to estimate the stochastic frontier using maximum likelihood Estimation method.

Aigner et al. (1977) suggested that the maximum likelihood estimates (MLE) of the parameters of model could be obtained in terms of parameterization.

\[ \sigma^2 = \sigma^2V + \sigma^2U \text{ and } \gamma = \frac{\sigma U}{\sigma V} \]

One advantage of estimating the frontier function is that it is possible to find out weather the farmers deviation of yield from frontier yield is mainly because he did not use the best practice technique or is due to external random factors. Thus one can say whether the difference between the actual yield obtained and the frontier yield if any occurred accidentally or not.

\[ \sigma^2 = \sigma^2V + \sigma^2U \text{ and } \gamma = \frac{\sigma^2U}{\sigma^2V} \]

### Mean Technical Efficiency

The average technical inefficiency (i.e.) the mean of the distribution of the \( u_i \) could be easily calculated. In the half-normal case (\( u_i \) distributed the absolute value of \( N(0, \sigma^2U) \) variables), the mean technical inefficiency is \( \sigma^2U\left(\frac{\sqrt{2/\pi}}{\sigma U}\right) \) and the technical efficiency is \( 1 - \sigma^2U\left(\frac{\sqrt{2/\pi}}{\sigma^2U}\right) \). The technical efficiency can be evaluated given one’s estimate of \( \sigma_u \). On an average, technical inefficiency could be estimated by the average of the \( E_i \).

### Resource Use Efficiency

In order to study the efficiency of resource use in Paddy cultivation the marginal value products (MVPs) of the resources were compared with its unit price (MIC).

The MVP of the individual input was worked out by,

\[
MVP \ X_i = b_i \frac{Y}{\bar{X}_i} \cdot P_y
\]

Where,

- \( b_i = \) Elasticity of Production
- \( \bar{Y} = \) geometric mean of output
- \( \bar{X}_i = \) geometric mean of input xi
\( P_y = \) price per unit output.

The input is used efficiently if the ratio between MVP and MIC is one. A ratio of more than one and less than one indicates under utilization and over utilization of the inputs respectively.

**Assumptions Used in the present Stochastic Frontier Model**

In the present study, the following assumptions were made which underline the specification of a stochastic frontier. The frontier is stochastic in nature due to factors beyond human control and symmetrical distributed error term present in it is responsible to capture the effects of outside random shocks. Observation and measurement error on the dependent variable and the other statistical ‘noise’. Variations in the technical efficiency of individual firms are due to factors completely under the control of farmers.

The production function fitted to the data in this study is of the form

\[
Y = b_0 X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} U_i
\]

Where,
- \( Y \) = Paddy output (kg/ac)
- \( X_1 \) = Quantity of seeds (kg/ac)
- \( X_2 \) = Labour (man hours/ac)
- \( X_3 \) = Machine Power and Bullock Power (Rs/ac)
- \( X_4 \) = Fertilizer (N + P + K) (kg/ac)
- \( b_0, b_1, b_2, b_3, b_4 \) = regression coefficients
- \( U_i \) = error term.

**Results and Discussion**

**Resource use efficiency**

To study the resource use efficiency in paddy cultivation, production function was estimated separately. The Cobb - Douglas form of production function was used and the production elasticity was estimated presented in Table 1.

From table 1 the coefficient of multiple determinations was 0.41 which indicated that 41.0 per cent of the variation in the dependent variable was explained by the explanatory variable for analysis. The variables fertilizer and machine power & bullock power were found to influence the yield significantly at one percent and ten per cent level, respectively. The results indicated that one per cent increase in fertilizer and non - human labour \( \text{ceteris paribus} \) would increase the yield by 0.42 and 0.05 per cent, respectively.
The results indicated that the table 2, ratio of MVP to factor cost was less than unity for machine & bullock power. This suggests that there exists over utilization of machine and bullock power. Thereby reducing the cost on machine and bullock power would be economically advantageous. The ratio of MVP to factor cost of fertilizer is greater than unity. This suggests that there exists under utilization of fertilizers. Hence, an increase in application of fertilizers would increase the yield of paddy further.

**Returns to Scale**

The sum of elasticities of resources is an indicator of the returns to scale. It could be observed that the sum of elasticities was 0.4822 indicating that it was lesser than unity. Therefore the paddy farms had decreasing returns to scale.

**Technical efficiency - Stochastic Production Frontier using Maximum Likelihood Estimation Method:** Efficiency is an important concept in production economics when resources are meager and opportunities for developing and adapting better technologies are competitive. Efficiency of a farm refers to its performance in the utilization of resources at its disposal. It is important to know; how well the resources are being utilized and possibilities exist for improving the operational efficiency of the resources. The results of stochastic frontier analysis are given in Table 3.

Revealed from the table 3, the variance of one-sided error term $\sigma^2U$ and symmetric error term $\sigma^2V$ were 0.17776 and 0.00010 respectively, which implied that the one-sided error term was dominant. The ratio of one sided error term to symmetric error term ($\lambda$) worked out to 42.161, which implied that the standard error of one-sided error term was greater than the standard error of symmetric error term. The estimates of the discrepancy parameter $\theta$ indicated that 99.0 per cent of the difference between the actual output and the maximum possible output were due to differences in technical efficiencies of farmers. The mean technical efficiency (MTE) was 0.6637, which implied that the yield of paddy was 33.6 per cent less than the maximum possible output. Thus the technical efficiencies revealed the scope for increasing the productivity of paddy at existing level of input use by the farmers.

The results indicated from table4, that 60.0 per cent of the farmers in the study area were technically efficient in the range of 60.0 - 80.0 per cent, 17.0 per cent of them were in the range of 40.0 - 60.0 per cent and also 20.0 - 40.0 per cent and only 7.0 per cent of the farmers were technically efficient in the range of 0 to 20.0 per cent.

Table 5 shows that the results indicated that the farmers who are technically efficient in the range of 0 – 20.0 per cent use a seed rate of 60 kg, labour 245 man hours and fertilizers @ 64
kg and machine and bullock power at the cost of Rs. 1252 and they obtain an yield of 655 kg ac\(^{-1}\). On the other hand, the farmers who are technically efficient in the range of 60.0 – 80.0 per cent apply a seed rate of 59 kg on an average, 313 man-hours of labour, 100 kg of fertilizers and Rs. 872 on machine and bullock power and he obtains a yield of 1611 kg. Thus the farmers who are 60.0 – 80.0 per cent technically efficient use the best combination of inputs in order to obtain the maximum output. Hence, the farmers who are 0 – 20.0 per cent technically efficient can improve the use of inputs in order to reach the level of 60.0 – 80.0 per cent technical efficiency and to achieve maximum output.

**Conclusions and Policy Implications**

The analysis revealed that there is an under utilization of fertilizers, which indicated that fertilizers use has to be increased. The use of machine and bullock power should be rationalized to increase the yield. Resource use efficiency analysis implied that there was an ample scope to increase the production by proper technology and optimum allocation of resources. Efficiency of farmers can be supported by mean technical efficiency, the results of which indicated that there is scope for further improvement in the technical efficiency of farmers in the study area.

Cost escalation is the most important factor, which makes rice cultivation a relatively less remunerative enterprise. So, reducing the cost of cultivation is the prime concern. Mechanization should therefore be allowed wherever possible to reduce the cost of labour. Although some of the factors of production like fertilizers and machine & bullock power affected paddy yield, yet the role of management is very important. Therefore, there is a need to reorient the existing extension strategies to guide the farmers regarding rational use of resources. The farmers located in inefficient groups need to be educated to achieve a higher level of production and profits through rational use of the resources at their command.

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5. Optimum Level of Inputs Use and Output
### Table 1. Resource Use Efficiency using OLS Method

<table>
<thead>
<tr>
<th>S. No</th>
<th>Particulars</th>
<th>Parameter values</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Constant</td>
<td>3.1104</td>
<td>2.823</td>
</tr>
<tr>
<td>2</td>
<td>Seed rate (kg ac(^{-1}))</td>
<td>0.84622</td>
<td>0.545</td>
</tr>
<tr>
<td>3</td>
<td>Labour (man hours ac(^{-1}))</td>
<td>-0.2987</td>
<td>0.392</td>
</tr>
<tr>
<td>4</td>
<td>Machine power + Bullock power (Rs. ac(^{-1}))</td>
<td>0.0573**</td>
<td>0.032</td>
</tr>
<tr>
<td>5</td>
<td>Fertilizer (N + P + K) (kg ac(^{-1}))</td>
<td>0.4249*</td>
<td>0.1305</td>
</tr>
<tr>
<td></td>
<td>(R^2)</td>
<td>0.4150</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Adjusted (R^2)</td>
<td>0.321</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(N)</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

* and ** - Significant at one and ten per cent level respectively

### Table 2. Estimation of over Use or under Use of inputs by Farmers

<table>
<thead>
<tr>
<th>S. No</th>
<th>Variable</th>
<th>Mean</th>
<th>AP</th>
<th>Elasticity Coefficient (bi)</th>
<th>MPP (Kg)</th>
<th>MVP</th>
<th>MVP/(P_x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yield (Kgs)</td>
<td>1393.267</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Machine &amp; Bullock power (Rs.)</td>
<td>898.281</td>
<td>1.5501</td>
<td>0.0573</td>
<td>0.0888</td>
<td>1.11</td>
<td>0.00019</td>
</tr>
<tr>
<td>3</td>
<td>Fertilizer (Kg)</td>
<td>94.381</td>
<td>14.7621</td>
<td>0.4249</td>
<td>6.2724</td>
<td>78.40</td>
<td>4.1702</td>
</tr>
</tbody>
</table>

### Table 3. Estimates of Stochastic Frontier Function for Rice Production

<table>
<thead>
<tr>
<th>S. No</th>
<th>Particulars</th>
<th>Parameter values</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Constant</td>
<td>6.1467*</td>
<td>1.6052</td>
</tr>
<tr>
<td>2</td>
<td>Seed rate (kg ac(^{-1}))</td>
<td>0.5715***</td>
<td>0.3473</td>
</tr>
<tr>
<td>3</td>
<td>Labour (man hours ac(^{-1}))</td>
<td>-0.5606***</td>
<td>0.2907</td>
</tr>
<tr>
<td>4</td>
<td>Machine and bullock power (Rs.ac(^{-1}))</td>
<td>0.1556**</td>
<td>0.7299</td>
</tr>
<tr>
<td>5</td>
<td>Fertilizer (N + P + K) (kg ac(^{-1}))</td>
<td>0.3050*</td>
<td>0.1070</td>
</tr>
<tr>
<td>6</td>
<td>(\sigma^2U)</td>
<td>0.17776</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>(\sigma^2V)</td>
<td>0.00010</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>(\lambda = \frac{\sigma_u}{\sigma_v})</td>
<td>42.161</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>(\theta = \frac{\sigma^2U}{\sigma^2U + \sigma^2V})</td>
<td>0.9994</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>(MTE = 1 - \sigma_u \sqrt{2/\pi})</td>
<td>0.6637</td>
<td></td>
</tr>
</tbody>
</table>

*, ** and *** - Significant at one, five and ten per cent level respectively
Table 4. Technical Efficiency of Sample Farmers

<table>
<thead>
<tr>
<th>S. No</th>
<th>Technical efficiency (%)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0 – 20.0</td>
<td>2 (7.0)</td>
</tr>
<tr>
<td>2</td>
<td>20.0 – 40.0</td>
<td>5 (17.0)</td>
</tr>
<tr>
<td>3</td>
<td>40.0 – 60.0</td>
<td>5 (17.0)</td>
</tr>
<tr>
<td>4</td>
<td>60.0 – 80.0</td>
<td>18 (60.0)</td>
</tr>
</tbody>
</table>

(Figures in parentheses denote percentage to total)

Table 5. Optimum Level of Inputs Use and Output

<table>
<thead>
<tr>
<th>Technical efficiency (%)</th>
<th>Seed rate (kg ac(^{-1}))</th>
<th>Labour (Man hours ac(^{-1}))</th>
<th>Fertilizers (kg ac(^{-1}))</th>
<th>Machine and bullock power (Rs. ac(^{-1}))</th>
<th>Yield (kg ac(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 – 20.0</td>
<td>60</td>
<td>245</td>
<td>64</td>
<td>1252</td>
<td>655</td>
</tr>
<tr>
<td>20.0 – 40.0</td>
<td>56</td>
<td>311</td>
<td>73</td>
<td>1071</td>
<td>838</td>
</tr>
<tr>
<td>40.0 – 60.0</td>
<td>63</td>
<td>296</td>
<td>110</td>
<td>743</td>
<td>1464</td>
</tr>
<tr>
<td>60.0 – 80.0</td>
<td>59</td>
<td>313</td>
<td>100</td>
<td>872</td>
<td>1611</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>305</td>
<td>95</td>
<td>985</td>
<td>1394</td>
</tr>
</tbody>
</table>

References

5. www.pondicherryagri.org