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RESEARCH ARTICLE

DETERMINANTS OF COST EFFICIENCY AMONG SUGARCANE FARMERS: A STOCHASTIC FRONTIER COST FUNCTION APPROACH

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ABSTRACT

The stochastic Frontier cost model was used to analyze the cost efficiency of Sugarcane farm households of Odisha. The primary data were collected from the 200 sugarcane farm households. The joint estimation of parameters of cost function and inefficiency model through one step maximum likelihood method showed that the 97% of the inefficiency were explained due to cost inefficiency and cost efficiency could be increased by 36% through better use of available farm resources. Since college education, average education of the family and experience significantly reduced cost efficiency, this could be achieved through farm specific inputs which include improved education of the effective farm household, better experience, improved education of the family and participation of more educated youth in farming practices. In addition to this, policy should be made for encouraging farm practices in higher education system so that formal education system can link agricultural system of the economy.

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INTRODUCTION

Agriculture is a way of life, which for centuries has shaped the thought, the outlook, the culture and the economic life of the people of India. Despite a steady decline of the share of agriculture in national income, the overall growth rate of the economy is largely determined by the performance of the agricultural sector. The pioneering work of Schultz, (1964), made it clear to many that to improve the lot of the poor people in low-income developing countries are not "space, energy and crop land; the determining factor is improvement in the human quality" Schultz (1971). Schultz (1981) in his 'investing in the human capital' pointed out that one of the fundamental mistakes done by the economists is understanding the human agents in agriculture—farm laborers and farm entrepreneurs who both work and allocate resources in the production. In the process of transforming agriculture from a traditional to a modern, dynamic and progressing state (from mid-Sixties onwards), not only the primary inputs but other non-tangible factors such as levels of schooling experience that brings a change in the quality of the human agent in using the available technology under the broad category of 'human capital' also play a vital role in improving production and productivity in farm production.

The complementarities of education with the access to new information, decoding the relevant information, the use of new inputs, adoption of new methods of production and reaping the maximum benefit out of it makes it very much useful to make an attempt to study the various forms of human capital such as formal schooling in various forms in addition to other primary inputs on improving individual farm efficiency. The productive value of education has its root in two distinct phenomena such as worker effect and allocative effect. Increased education simply may permit a worker to accomplish more with resources at hand. This 'Worker effect' is the marginal product of education as it is normally defined,

that is the increased output per unit change in education holding other factor quantities constant. On the other hand, increased education may enhance the worker's ability to acquire and decode information and cost and productive characteristics of other inputs. As such a change in education results in a change in other inputs including perhaps the use of some new factors that otherwise would not have used. This is called allocative effect. In a pioneering study exploring the economic effects of education, Griliches (1958) used production function analysis to highlight the contribution of education in agricultural productivity. However, following Welch (1970), the subsequent literature has not deemed it necessary to maintain the distinction between the innovative and allocative effect. Evidence from 13 low-income countries shows that farm productivity, on an average, increases by 8.7 percent as a result of a farm completing four years of elementary education (Lockheed *et al.*, 1980). Bikhauser *et al.* (1991) reviewed Forty-seven studies from 17 countries and found that 33 studies show significant and positive extension effect. Research towards identifying and understanding the role of education in production can be categorized into two parts.

In the first part, the technical efficiency part is investigated between two groups of farmers either educated or uneducated or traditional and modern farmers (Welch, 1970; Moock, 1981; Lockheed *et al.*, 1980; Pudasaini, 1983; Azhar, 1991). The studies analyzed both technical and allocative effect part of education are (Welch, 1970; Ram, 1980; Pudasaini, 1982, 1983; Duraiswamy, 1990, 1992; Mohapatra, 1998). A detailed review is presented in Tilak (1993). The pioneering work of Farrell (1957) on the measurement of efficiency and the introduction of stochastic frontier models, independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Vanden Broeck (1977) and extended by Jondrow *et al.*, (1982) brought a large number of empirical studies of measuring technical, allocative and economic efficiency of the farms with special reference to education age and experience of the farms using cross sectional data (Kalirajan 1981, 1990; Squires and Tabor 1991; Bravo-Ureta and Pinheiro, 1997; Hwang and Bagi 1984; Ogundari *et al.*, 2006). According to the studies reviewed by Bravo-Ureta and Pinheiro (1993), it can be argued with justification that stochastic

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models are more reliable than the deterministic models because the former account for statistical noise. In case of the simple Cobb-Douglas production function, on an average, the percentage gain in output for each year of education is around 3.5%. In case of the stochastic frontier methodology using the cross section data, the TE and AE are 70% and 68%. The average TE and EE for the studies using dual frontier are 88% and 69% respectively and TE, AE and EE for the studies using deterministic frontier are 63%, 68% and 32% respectively. This paper aimed at better understanding of small scale sugarcane farmers of the study area (Jajpur district of Odisha) with a view to predicting cost efficiency (a measure of farm's ability to produce at a given level of output using cost minimization input ratio of 200 farmers), using stochastic frontier cost function in which the maximum likelihood estimates of the parameters of cost function and the linear inefficiency function have been obtained jointly through FRONTIER-4.1c Coelli (1996). The differences in cost efficiency among the farm households are explained with special reference to schooling of the farmers, education of the family and experience of the farm household.

MATERIALS AND METHODS

The data used in this paper are directly collected from the farm households of the study area (Goleipur Panchayat of Korei block, Jajpur district, Odisha) through a questionnaire. The specific area of the study is chosen because of its well road and transport connectivity through National Highway, multi-cropping pattern and existence of big markets. With a formal permission taken from the sarpancha of the Village Panchayat, Six villages have been selected for collecting information from 200 farm households. The stochastic frontier approach, based on a specific functional form introduced by Aigner, Lovell Schmidt (1977) and Meeusen and Van den Broeck (1977), is motivated by the idea that the deviation from the frontier may not be entirely attributed to the inefficiency because random shocks outside the control of the farmers can also affect the output. The cost function can be used simultaneously to predict both technical and allocative efficiency of a farm (Coelli, 1995). Also it can be used to resurrect all the economically relevant information about farm level technology as it is generally positive, non-decreasing, concave continuous and homogeneous to degree one to input prices (Chambers, 1983). In this study, Battese and Coelli (1995) model is used to specify a stochastic frontier cost function with behavior inefficiency component and to estimate all parameters together in one step maximum likelihood estimation. The model is implicitly expressed as:

$$\ln C_i = g(Y_i, P_i; \alpha) + (v_i + u_i) \quad \text{-----} 1$$

Where C_i represents the total cost of production of the i th farm household; g is a suitable functional form such as Cobb-Douglas; P_i is a vector variable of input prices; Y_i is sugarcane output in Kgs; α is the parameter to be estimated. The systematic component v_i represents random disturbances of cost due to factors outside the scope of the farmers. It is assumed to be identically and normally distributed with mean zero and constant variance as $N(0, \sigma_v^2)$. u_i is the one sided disturbance form used to represent cost inefficiency and is independent of v_i . Thus $u_i = 0$ for a farm whose cost lie on the frontier, $u_i > 0$ whose cost lie above the frontier; $u_i < 0$ whose cost lie below the frontier. u_i is identically and independently distributed as $N(0, \sigma_u^2)$. The two error terms are preceded by positive signs because inefficiencies are always assumed to increase the cost. Cost efficiency¹ (C_{EE}) of an individual farm is defined in terms of the ratio of observed cost (C_{OB}) to the corresponding minimum cost (C_{MIN}) given the available technology.

¹ In this cost function u_i now defines how far the farm operates above the cost frontier. If allocative efficiency is assumed, the u_i is closely related to the cost of technical inefficiency. If this assumption is not made, the interpretation of u_i in a cost function is less clear, with both technical and allocative inefficiencies involved. Thus we shall refer to efficiencies measured relative to a cost frontier as 'cost' efficiencies in this document. The exact interpretation of these cost efficiencies will depend upon the particular application.

$$(C_{EE}) = (C_{OB}) / (C_{MIN}) = \{g(Y_i, P_i; \alpha) + (v_i + u_i) / g(Y_i, P_i; \alpha) + (v_i)\} = \exp(v_i) \quad \text{-----} (2)$$

(C_{EE}) takes 1 or higher than 1 defining cost efficient farm. Following the adoption of Battese and Coelli (1995) framework for the analysis of data, the explicit Cobb-Douglas functional form for the sugarcane data of the study area is, therefore, specified as:

$$\ln C_{pi} = \ln \alpha_0 + \alpha_1 \ln Y_{ii} + \alpha_2 \ln P_{1i} + \alpha_3 \ln P_{2i} + \alpha_4 \ln P_{3i} + \alpha_5 \ln P_{4i} + \alpha_6 \ln P_{5i} + \alpha_7 \ln P_{6i} + (v_i + u_i) \quad \text{-----} (3)$$

It represents the Frontier total cost function for sugarcane production of the study area; C_{pi} stands for the total cost (in Rs.) of production for the i th farm; Y_i stands for the total sugarcane output (in Kg.) produced by the i th farm household. In equation (3), P_1 to P_6 represent cost of labor, bullock labor, Nitrogen, irrigation and cost of tractor hours. The choice of the Cobb-Douglas functional form is based on the fact that the function is self-dual as in the case of cost function in which the present analysis is based on. The inefficiency models for the above sugarcane cost frontier is defined as:

$$U_{si} = \delta_0 + \delta_1 EF + \delta_2 EX + \delta_3 E + D_1 EDU + D_2 EDU + D_3 EDU \quad \text{-----} (4)$$

Where, U_{si} are the cost inefficiency component for sugarcane. EF refers to the average education of the family; EX represents the experience of the effective head of the household; E refers to the levels of formal schooling year completed by the effective head farm household² and D_1 refers to education dummy for college level education; D_2 represents the higher secondary education dummy and D_3 represents the primary and higher primary schooling dummy. These exogenous intangible variables are included to examine their impact on the cost efficiency of the farmers. The δ_i , s and D_i , s are the scalar parameters to be estimated. The variance of the random error, σ_v^2 , and the cost inefficiency error σ_u^2 and overall variance of the model σ^2 are related as follows: $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$. The Gamma (γ) measures the total variation of the total cost from the frontier cost which can be attributed to cost inefficiency (Battese and Corra, 1977). The estimates for all the parameters are simultaneously obtained using the programme FRONTIER 4.1 (Coelli, 1996). The test for the presence of cost inefficiency using generalized likelihood ratio statistics λ obtained by $\lambda = -2 \ln (H_0/H_a)$. If the null hypothesis is true then λ has approximately a mixed chi-square distribution with degrees of freedom equal to the number of parameters excluded in the unrestricted model.

RESULTS AND DISCUSSION

Table 1 is presented with the summary statistics of the variables in the sugarcane stochastic cost frontier model. The mean total cost of sugarcane cultivation is 11630 with minimum of 5554 and maximum of 32075. The huge range of total cost clearly indicates that the range of cultivation of sugarcane is also very high. Since more financial investment and more time are required, some farmers do not cultivate more area under the crop. The high labor cost share in the total cost is due to the fact that sugarcane cultivation takes longer period (18 months to 20 months), plenty of manual labor works are to be used; the use of labor power is comparatively more. Second thing is that, sugarcane cultivation requires use of different fertilizer in different times. Hence, the share of each fertilizer is estimated. The maximum share is by Nitrogen (Urea) is 4.74 per cent followed by calcium (3.01%) and Super (2.05%). The high share of irrigation cost (10.28%) also indicates the importance of continuous requirement of water in the sugarcane production. It should be

² While collecting the sample, it has been observed that the head of the farm household, most often, is not the real cultivator. Hence, the family member who cultivates the farm takes the major decision regarding farm production. Hence, he is designated by the term "effective head of the household".

Table 1. Summary Statistics of Variables in the Sugarcane Stochastic Cost Frontier Model (In Rupees)

| Variable | Mean (Rupees) | Standard Deviation (Rupees) | Minimum (Rupees) | Maximum (Rupees) | % of the total cost |
|--|---------------|-----------------------------|------------------|------------------|---------------------|
| TC | 11630 | 5554 | 5600 | 32075 | |
| VO | 2709.5 | 1377.6 | 7080 | 51200 | |
| Labor cost | 4576.8 | 2202 | 640 | 12400 | 39.35 |
| Bullock labor cost | 245.2 | 1335.7 | 840 | 10500 | 2.2 |
| Urea cost | 551.70 | 315.7 | 175 | 3750 | 4.74 |
| Potash cost | 230 | 149 | 80 | 1500 | 1.28 |
| Super cost | 239.55 | 126.87 | 60 | 750 | 2.05 |
| Calcium cost | 350.475 | 202.33 | 75 | 1125 | 3.01 |
| Manure cost | 34.31 | 18.47 | 12 | 120 | 0.3 |
| Tractor cost | 1906.5 | 983.85 | 600 | 5400 | 16.4 |
| Irrigation cost | 1195.6 | 598.04 | 160 | 4000 | 10.28 |
| Average Education of the Family* | 8.270 | 2.514 | 4 | 10 | |
| Average Education of the effective head* | 8.13 | 2.35 | 3 | 13 | |
| Experience* | 8.21 | 2.521 | 3 | 13 | |

*The figures are in number of years of farming experience in growing sugarcane

Table 2. Maximum-likelihood Estimates of Parameters of Cobb-Douglas Frontier Cost Function for the Sugarcane Farm Household

| Parameters of Variables | Estimate of Parameters | 't' Value of parameters |
|---|------------------------|-------------------------|
| β_0 (constant) | 0.3523 | 3.6202* |
| β_1 (ln Output) | 1.14 | 2.34** |
| β_2 (ln Labor cost) | 0.5126 | 5.516* |
| β_3 (ln Bullock cost) | 0.3646 | 4.027* |
| β_4 (ln Urea cost) | 0.5949 | 6.023* |
| β_5 (ln Potash cost) | 0.1996 | 2.005** |
| β_6 (ln Irrigation cost) | 0.10002 | 10.04* |
| B_7 (ln Tractor cost) | 0.3827 | 4.42* |
| Inefficiency Model | | |
| δ_0 (inefficiency constant) | -0.1386 | 13.91* |
| δ_1 (Average Education of Family) | -0.2047 | 2.06** |
| δ_2 (Experience of the effective head) | -0.0752 | 9.85* |
| δ_3 (Education of effective head) | -0.1889 | 5.063* |
| D_1 EDU | -0.0739 | -02.503** |
| D_2 EDU | -0.2777 | 0.7421 |
| D_3 EDU | -0.0029 | 0.2948 |
| σ^2 | 0.2184 | 21.29* |
| γ (Gamma) | 0.97 | 23.76* |
| Log likelihood Function | 347.59 | |

** , * Show 5% and 1% level of significance respectively.

mentioned that most the farm households in the study area use diesel water pump (Five Horse Power) for irrigating their sugarcane fields. The significant share of the tractor hour is proved from the fact that, the traditional bullock driven plough wood cultivation cannot achieve deeper cultivation of the land, as it is essential for sugarcane crop. Secondly, the easy availability of tractors power tillers in the local area and the consequent hiring cost benefit for the farmers are another factor for the large share of the tractor cost in the total cost. The results of the joint estimation of the parameters of the stochastic Cobb-Douglas cost frontier for sugarcane are presented in the Table 2.

All the beta coefficients of the sugarcane stochastic frontier cost function were statistically significant. It shown the relevance of the input prices and the volume of output in the sugarcane cost function of the study area. Sugarcane crop belongs to *Gramineae*, the grass family. It responds well to nutrition and water management. Sugarcane productivity can increase if appropriate irrigation and fertilizer management is followed. Preparatory tillage is very important operation in sugarcane cultivation. Sugarcane roots penetrate up to 90 centimeters deep in the soil and, hence, for better growth tillage has an important effect. Soil preparation must destroy the stumps of the old canes and improve any bad physical soil characteristics or loss of structure those have developed during the previous year. In this background it can be argued that the importance of both bullock driven plough wood tilling and tractor tilling is very much prominent. The use of fertilizer such as nitrogen, potash and

phosphorous and irrigation is utmost essential. This in fact was revealed from the results of the statistically significant beta coefficients of the sugarcane frontier cost function of the study area. The model without inefficiency components was tested against the model with efficiency components and the null hypothesis that there is no difference between these two models was rejected at 1% level of significance. The likelihood function value for without inefficiency component was 101.78 and the corresponding value for the alternative is 347.59. From the gamma value (γ), it was concluded that 97% of the inefficiency was due to the cost inefficiency which was attributed to education of the family of the effective head of the household, experience of the effective head of the household and the education of the effective head.

All these factors, of course, contributed positively in reducing cost inefficiency, the differences came when the education of the effective head was used as a dummy variable. In case of college education, the dummy D_1 was statistically significant in reducing the cost inefficiency in the sugarcane production. This supports the study (Nandolnyak *et al.*, 2006; Asogwa, 2011). Since sugarcane production takes 16 to 18 months, lots of care has to be taken by the farmers. For example, preparation of the soil suited for plantation; preparation of plant cuttings and culture of plant cuttings, use of proper dose of fertilizer in appropriate time; choice of irrigation method such as, flood irrigation and drip irrigation. It was also realized that the farmers with more schooling specially college level are more prone to better management with efficient method of production as stated above, many farmers used drip irrigation which

saved 30 to 40 per cent of the water and also thereby the diesel and electricity consumption also reduced accordingly. On the other side, the farmers with little education, of course, have contribution but not statistically significant. Some time the wrong choice of using bullock labor instead of tractor for initial cultivation reduces cost efficiency. Ever since Chaudhuri (1974) has articulated this idea as "Lapses back into illiteracy". According to Nelson-Phelps-Schultz hypothesis (1986) the effect of education is supposed to differ over time, as time passes and new technological diffusions are made in the field of agriculture, the knowledge from either primary schooling or from higher primary schooling will be totally useless in acquiring useful information and decoding them for the farm practices. Hence, the hypothesis that education of the effective farm households has positive and statistically significant impact is accepted. The frequency distribution table of farm level cost inefficiency, the corresponding frequency and its percentage of farm household belong to each category are presented in the Table 3. The frequency distribution of sugarcane cost efficiency scores are presented in the Table 3. The average efficiency score was 1.365. Sixty Nine per cent of the total farm households had scores in between 1.2 to 1.39 and 25 % were in the range of 1.4 to 1.59. There is chance that the cost inefficiency scores can be reduced, on an average, by 36 % in comparison to the frontier cost

Table 3. Frequency Distribution of Cost Efficiency for Sugarcane Farm-households

| Class Interval (C _{EE}) | Frequencies | Percentage |
|-----------------------------------|-------------|------------|
| 1.0 - 1.19 | 8 | 4 |
| 1.2 - 1.39 | 138 | 69 |
| 1.4 - 1.59 | 50 | 25 |
| 1.6 - 1.79 | 0 | 0 |
| 1.8 - 1.99 | 2 | 1 |
| 2.0 - 2.19 | 2 | 1 |
| Average | 1.365 | |

Conclusion

The implication of the study is that the farmers were not minimizing the production cost indicating that the cost efficiency among the sugarcane farmers could be increased by 36 % through better use of the available resources given the current state of technology. This could be achieved through improved education of the farmer, improved farm experience, higher family education. The government should provide better incentives to the educated youths to actively participate in various farm management activities. More farm extension services to the farm households can improve the experience in practicing modern farm management practices thereby improving farm production and productivity helping an accelerated economic growth

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