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RESOURCE USE EFFICIENCY IN SUGARCANE PRODUCTION IN BIHAR (INDIA): A STOCHASTIC FRONTIER ANALYSIS

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Abstract

India is the second largest producer of sugar after Brazil accounts for 16 percent of world production. In Bihar, Sugarcane was cultivated in about 2.64 lakh hectare (5.02% of India's sugarcane area) with a production of 181.76 lakh tonnes and shares 4.17% of total production of the country during 2015-16. Bihar was once reckoned as second largest sugar producing state but it has lost its traditional position to peninsular states. The study is based on plot level data of Comprehensive Cost of Cultivation Scheme, Ministry of Agriculture and Farmers Welfare, Government of India running in Bihar for the period 2013-14. The objectives of the study were to determine technical efficiency of the cultivators in using resource inputs and to access the impact of socio-economic factors on sugarcane production in the state. The resource inputs were found inelastic and not being properly utilized. All the resource inputs were found significant at 1% and 5% level of probability except machine labour and fertilizers used. In inefficiency model landholding size, age and family size were estimated negative, indicating positive impact on efficiency in sugarcane production. The effect of education was accessed positive indicating increase in formal education raised inefficiency. The mean technical efficiency was estimated to be 0.92 indicted that optimal and sustainable use of resource inputs may raise further, the sugarcane production by 8% and boost up the income of the sugarcane growers of the state.
Key words: Sugarcane, Technical efficiency, Stochastic Frontier Production Function, Resource inputs, income

Introduction

Sugarcane is one of the most important crops in the world because of its strategic position and immense uses in daily life of any country as well as industrial uses aimed at nutritional and economic sustenance (Onwueme and Sinha, 1991). It contributes about 60% of the total world sugar requirement and rest 40% comes from sugar beet. It is tropical crop that usually takes 8 to 12 months to reach its maturity. India is the second largest producer of sugar after Brazil accounts for 16 percent of world production. Sugarcane production achieved a record of 361 million tonnes in 2011-12, after which it declined to 341 million tonnes in 2012-13 and then increased to 359 million tonnes in 2014-15. Out of this, 266 million tonnes i.e. 74 percent of total sugarcane production was crushed for sugar production in 2014-15 and the remaining could have been used for production of jaggery, khandsari etc. It is the second important cash crop in India, contributing direct and indirect employment to 45 million farmers and large mass of skilled and unskilled workers are engaged in sugarcane cultivation, harvesting and ancillary activities (Raut *et. al.,* 2017). Even though sugarcane cultivation occupied about 2.5 percent India's gross cropped area (2014-15) and its products accounted for 6 percent of the total value of agricultural output.

In India, there are two distinct regions for sugarcane cultivation, tropical comprising cane producing southern states of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu and subtropical comprising northern states of Bihar, Uttarakhand and Uttar Pradesh. Subtropical region, encompassing 55 percent of total cane area, contributes only 48 percent of total cane production and 35 percent of total sugar production in the country, whereas tropical region covers 41 percent of the cane area, contributes 49 percent of the cane production and 64 percent of sugar production. The average cane productivity in subtropical region was found to be 61 tonnes/hectare and 84 tonnes/hectare in tropical region in the year, 2014-15. The rest of the cane production comes from states not lying in these two regions.

Bihar was once reckoned as second largest sugar producing state but it has lost its traditional position to peninsular states. In Bihar, Sugarcane was cultivated in about 2.64 lakh hectare (5.02% of India's sugarcane area) with a production of 181.76 lakh tonnes and shares 4.17% of total production of the country during 2015-16. Sugarcane is cultivated in almost all districts of Bihar. Further, West Champaran (46.57%), East Champaran (16.43%), Gopalganj (9.86%) Sitamarhi (5.56%), Muzaffarpur (3.08%), Begusarai (2.51%) and Samastipur (2.26%) are known as major districts which accounted for larger percentage of total area under sugarcane in the state. Nalanda, Patna and Bhojpur districts were the top three districts as per productivity of sugarcane (2015-16).

Production of sugarcane crop is a complex process and depends on various combinations of input uses such as human labour, machine lablour, fertilizers, irrigation, capital and management practices etc. The variations in use of different combinations of resources affect the production and yield of sugarcane. These combinations of inputs are known as technology. Cultivators experience variation in sugarcane yield that is the result of varying level and combinations of input uses. Furthermore, there is wide yield gap between farmer's field and experimental fields, indicating the suboptimal uses of inputs. Technical efficiency depicts the conversion of different physical inputs such as human labour, machine labour, groundwater use (irrigation) and use of fertilizers into output/yield.

In this investigation, attempt has been made to assess the efficiency of different resource inputs as well as impact of socio-economic factors on technical efficiency of sugarcane cultivators of the state.

Technical efficiency measurement using Stochastic Production Frontier model

Stochastic production frontier analysis has been widely used approach for estimation of the technical efficiency in various settings of the farm production function (Aigner *et.al.,* 1977, Meeusen and Van den Broeck, 1977). The approach has two components: a stochastic production frontier serving as a benchmark against which firm efficiency is measured, and a one-sided error term which has an independent and identical distribution across observations and captures technical efficiency across production units (Yanyan, 2006).

According to Sunday *et.al.,* 2013, Stochastic Production Frontier Analysis indicates the maximum expected output for a given set of inputs. It is derived from the production theory and based on the assumption that output is a function of inputs and efficiency of the producer in using these inputs. This function assumes that the boundary of production function is defined by "best practice" firms. It, therefore, indicates the maximum potential output for a given set of inputs. The difference between observed output and potential output is generally attributed to combination of inefficiency and random error.

Battese *et.al.,* 1995 and Fari *et. al.,* 2001 defined the Stochastic Production Frontier (SPF) as given below:

$$Y_j = f(X_{ij}; \beta) \exp \epsilon$$

$\epsilon = V_j - U_j$ where, j=1, 2,…… N and i=1,2,,…5

Where Y_j is the output of j^{th} firm, X_i is a vector of factor inputs to be used by j^{th} firm, β is the vector of unknown parameters to be estimated, 0 is a composite error term, V_j is the stochastic error term which is associated with random factors outside the farmers control such as topography, weather and it is independent of U_j. The U_j is a one-sided error representing the technical inefficiency of firm j. Both V_j and U_j are assumed to be independently and identically distributed with constant variance and zero mean.

The technical efficiency (TE) of a firm using Stochastic Production Frontier is given as:

$$TE = \frac{Y_j}{Y_j^*} = \frac{\text{Observed output}}{\text{Frontier output}} = \frac{f(X_{ij};\ \beta)\exp(V_j - U_j)}{f(X_{ij};\beta)\exp(V_j)}$$

Materials and Methods

The study is based on plot level data collected under Comprehensive Cost of Cultivation Scheme, Ministry of Agriculture and Farmers Welfare, Government of India running in the state of Bihar for the year, 2013-14. Since, the number of respondents in the sample was very few, An extra survey on the schedules, (Record Types-RTs) of Comprehensive Cost Cultivation Scheme were used to collect data from the major sugarcane growing districts of the state, ten respondents from each district were taken purposively. Thus, the total number of respondents was 80.

Model Specification for sugarcane farmers

The empirical stochastic frontier production model is specified as given below:

$$\ln Y_j = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + (V_j - U_j) \ldots\ldots(1)$$

Where,

Y= Production of sugarcane (tonnes/ha)

X_1= Human labour (hr/ha)

X_2= Machine labour (hr/ha)

X_3= Seed (Setts) (q/ha)

X_4= Groundwater (cum/ha)

X_5= Fertilizer (kg/ha)

V_j= Stochastic error term

U_j = Technical inefficiency effect predicted by the model

The *a priori* expectation is that the coefficients of all the inputs X_1 to X_5 which are β_1 to β_5 should be positive, respectively.

The inefficiency model is as follows:

$$U_j = \delta_0 + \delta_j Z_{ij} \ldots.. (2)$$

Where:

U_j= Technical inefficiency effect

Z_{ij}=Values of explanatory variables for technical inefficiency effects for the j^{th} farmer

Z_1= Total land of j^{th} farmer (ha)

Z_2= Age of the j^{th} farmer

Z_3= Educational level of j^{th} farmer

Z_4= Family size of j^{th} farmer

The specification of the model for inefficiency effects in equation (2) implies that, if the independent variables of the inefficiency model have a negative sign on the estimated parameter, then the associated variable has positive impact on efficiency, while positive sign indicates that the reverse is true.

Results and Discussion

Summary statistics of different inputs and output is presented in the Table1. The average production of sugarcane was observed to be 53.62 tonnes/ha. The use of human labour was obtained on an average, 1028.78 hr/ha, 3.19 hr/ha machine labour, sugarcane seed (setts) 84.86 q/ha, groundwater irrigation being 6179.11 cum/ha and fertilizers 201.37 kg/ha, respectively. According to Directorate of Economics and Statistics, Government of Bihar, the output of sugarcane was reported to be 46.99 tonnes/ha in 2010-11 and 51.71 tonnes/ha in 2011-12. According to FAOSTAT (2013), the world average yield of sugarcane in the year 2012 was 69.56 tonnes/ha. About 100-120 quintals seed (setts) and about 550 kg fertilizers are required for planting sugarcane in one hectare of land. As per Indian Institute of Sugarcane Research (2011), about 400-520 hrs human labour are required for a normal sugarcane farming excluding harvesting. The study clearly indicated that the farmers were producing below the potential yield of sugarcane and the inputs were being used in unbalanced manner either under or over utilized. This may be due to unawareness about the new sugarcane farming technology and were using unimproved seed (setts). The other reason for low productivity of sugarcane may be the traditional method of farming.

Table 1: Input and output levels for sugarcane production in Bihar

Variables	Maximum	Minimum	Mean	Standard Deviation
Output (tonnes/ha)	84.00	33.30	53.62	13.68
Human labour (hr/ha)	2487.78	428.0	1028.78	407.98
Machine Labour (hr/ha)	11.88	0.28	3.19	2.43
Seed (setts) (q/ha)	113.46	30.40	84.86	17.29
Groundwater draft(cum/ha)	14438.99	1131.15	6179.11	3855.12
Fertilizer (kg/ha)	595.74	107.50	201.37	78.78

Resource use efficiency in sugarcane cultivation

The resource use efficiency aimed at investigating the technical relationship between resource inputs used and output which were not efficiently managed by the cultivators, resulting in low productivity in sugarcane in the state of Bihar. The Maximum Likelihood Estimates (MLE) of the stochastic frontier production model and the inefficiency model were estimated using FRONTIER 4.1c software developed by TJ Coelli and the results were shown in Table 2.

The estimates depicted that coefficients of the resource inputs had positive sign, thus conformed to the *a priori* expectation. Human labour, seed (setts) and groundwater used were found statistically significant at 1% and 5% level of probability. These inputs were found to be relatively, inelastic and not being used properly. Hence, optimal use of these resources may increase the productivity level.

The estimated coefficient of human labour was 0.218. This indicates that 10% increase in human labour, other things being equal, increases sugarcane output by 2.18%. This revealed that labour in the state was inelastic too. This finding agrees with the findings of Amodu *et. al.* (2011) who revealed labour in study area had positive and significant impact. This shows the importance of labour in farming, especially in the state of Bihar, where mechanized way of farming becomes unaffordable as majority of cultivators were marginal and small.

Table 2: Results of maximum likelihood estimates of stochastic frontier production function for sugarcane production

Variables	Coefficient	Standard-error	t-ratio
Constant	2.257	1.113	2.028**
Human labour (ha/ha)	0.218	0.064	3.396*
Machine Labour (ha/ha)	0.014	0.034	0.397
Seed (setts) (q/ha)	0.175	0.084	2.093**
Groundwater used(cum/ha)	0.113	0.047	2.407*
Fertilizer (kg/ha)	0.103	0.087	1.190
Constant	0.707	0.206	3.430*
Landholding	-0.0002	0.012	-0.015

Size(ha)			
Age (years)	-0.004	0.003	-1.148
Education	0.014	0.025	0.563
Family size	-0.0072	0.011	-0.630
sigma-squared (δ^2)	0.0485	0.014	3.54*
Gamma (γ)	0.990	1.753	0.571

**, ** indicates significant at 1% and 5% probability level*

The coefficient of machine labour was found 0.014, which revealed that 10 percent increase in machine labour will increase the production upto 0.14%, other inputs being same. The coefficient of seed (setts) was observed to be positive and significant reflecting thereby 10% increase in setts will boost up the production of sugarcane by 1.75%. The estimated coefficients of groundwater use was found 0.113, which was observed significant, at 1% level of probability indicating that 10% increase in irrigation will increase the output by 1.13%, other things being the same. In case of fertilizer use, the coefficients estimated was found to be 0.103 which was positive, revealed that augmenting 10% fertilizer use in sugarcane production will push up productivity by 1.03%. This result conformed the findings of Sulaiman *et. al.,* (2015) and GS Umos (2006). In their study, the coefficient of fertilize use was found positive and significant.

From the forgoing estimated coefficients of resource used in sugarcane production, it can be stated that there is a wide potential of enhancing sugarcane production by proper and efficient utilization of resource inputs in the state.

Effect of socio-economic factors on sugarcane production

The inefficiency model as presented in Table 2 revealed that only the estimated coefficients of landholding size, age and family size conformed to the *a priori* expectation. A negative coefficient in efficiency model shows the positive effect on efficiency i.e. it increases the technical efficiency and production, while a positive sign indicates negative impact on efficiency i.e. decreases technical efficiency resulting in decrease in production of sugarcane.

The coefficient of age was found to be -0.004. This implies that there is negative relationship between age and technical inefficiency in sugarcane production. Age of the cultivators play an important role in decision making and has contribution towards cultivators general learning and right judgments in time. Hence, with increase in farmer's age, farmers got expertise in farming and become more efficient. Similar result was also obtained by Amjad and Abbas (2017) and Berniam *et. al.,*(2004). The coefficients of total landholding size and family size were estimated to be -0.0002 and -0.0072, which indicated that these factors had positive impact on technical efficiency of the sugarcane growers of the state. Mechanization of large holding is easy and cost effective as compared to small and marginal land holdings. Number of family members will provide more hands for farming and will reduce dependency on hired labour as sugarcane cultivation is labour intensive. Hence, sugarcane growers may be able to manage their farms efficiently as the labour scarcity in the state for cultivation purpose is also a big problem.

The coefficient of total education was found positive thus, failed to conform to the *a priori* expectation. The coefficient of education (0.014) was found to be positive reflecting positive relationship between technical inefficiency and education. This shows that increase in formal education would increase inefficiency or decrease the production efficiency. It may be that cultivators are using traditional methods of farming or educated people did not want to indulge themselves in faming profession. They were more attracted towards non-farm activities. The result agrees with the results of Musab and Bwacha (2010).

The variance parameters of the frontier production model were Sigma square (δ^2) and Gamma (γ). The Sigma squared indicates the total amount of variance found in the model. It was found 0.0485 which was statistically significant at 1% level of probability. Gamma explains the systematic impacts that are unexplained by the production function and the dominant sources of random errors. It was estimated 0.99. This shows that 99% variation in sugarcane production was as a result of technical inefficiencies of the cultivators. Thus, the results indicate that inefficiencies were present in the state in production of sugarcane.

Technical efficiency indices among sugarcane cultivators

The technical efficiency of individual farmers is presented in Table 3 as obtained from Stochastic Frontier Production model. It was observed that mean technical efficiency was found to be 0.92 which indicated that optimal production can be achieved by enhancing efficiency by 8.0% in the state. As much as 76.25% sample farmers were found efficient more than 0.90 efficiency level. Percentage of sample farmers in efficiency level upto 0.89 was found to be 23.75 which revealed that there was scope to enhance the efficiency of the farmers henceforth; the optimum output could be achieved through application of proper combination and utilization of resource inputs in the state.

Table 3: Technical efficiency indices among sugarcane farmers

Efficiency intervals	Percentage
0.20-0.29	0.00
0.30-0.39	0.00
0.40-0.49	0.00
0.50-0.59	0.00
0.60-0.69	0.00
0.70-0.79	0.00
0.80-0.89	23.75
≥0.90	76.25
Maximum efficiency	0.99
Minimum efficiency	0.85
Mean efficiency	0.92

Conclusion

It may be summarized from the study that the technical efficiency in sugarcane production was found positively related to landholding size, age and family size of the cultivators. The socio-economic factor education was found negatively related the technical efficiencies of the farmers as educated people are more attracted towards non-farm activities. The resource inputs such as human labour, machine labour, seed (setts) and fertilizers were positively related to the output of sugarcane in the state. The technical efficiency indices also suggested that there is a scope of enhancing technical efficiency of the sugarcane farmers by 8.0% in the state of Bihar.

The resource inputs such as such as human labour, machine labour, seed (setts) and fertilizers in sugarcane production in the state were not utilized efficiently resulting in low productivity of sugarcane. Thus, in order to enhance the technical efficiency of different inputs, it is imperative for providing proper training to the sugarcane cultivators of the state regarding proper and optimal utilization of available resource inputs for fetching optimum income from sugarcane cultivation. The government agencies and policy makers would have to come forward to address the problems and come out with stable solution for sugarcane growers in the state. Further, sugarcane growers should form a formal strong association that would represent their right interest so as to help them to acquire upto-date-information about sugarcane cultivation and access to financial and technical supports from the government and stakeholders like sugarcane mills in the state.

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