Economic and Technical Efficiency of Maize Production in the Eastern District of Bhutan: Stochastic Frontier Approach

ABSTRACT

This research paper seeks to deal with the problem of economic and technical efficiency of maize farmers located in the eastern region of Bhutan. For the objective of this paper, the stochastic frontier parametric approach was employed. The socio-economic and production data were collected from 120 maize growing farmers using simple random sampling technique for the production year 2020-2021. Results show that maize producing farmers are 81.47 %technically efficient and 78.19 %economically efficient in producing maize. Farm size, household size, and training positively influences the maize efficiency. The paper presents supporting evidence for more government policy in terms of provision of subsidies on agrochemicals and providing training for better management skills to the farmers.

Keywords: Efficiency, Production, Policy, Input, Output, Technical

1. INTRODUCTION

Bhutan is largely an agrarian economy (62.2%) categorized by smallholders' farmers mainly based on self-sustaining integrated farming with marginal land holdings (Katwal, 2013). Agriculture plays an important role in the economy, employing more than 54% of the country's population. Agriculture sector is one of the most important contributors to a country's GDP and leads tothe livelihood of a large proportion of the population. Maize (*Zea mays*) is the second most staple food grain after rice, constituting 43.7% of the national food composition (DoA, 2021). The total production and the national maize productivity stands at 74, 370 ton and 1.224 ton/ac (DoA, 2018). Maize is an important cereal crop mostly grown in eastern Bhutan accounting for 45% of annual maize production in the country (Wangmo, 2019). The Royal Government of Bhutan (RGoB) recognizes the critical role of food self-sufficiency and have introduced various strategies for improving maize production. Therefore, improving the production and productivity of maize crops is crucial to food security of the country. However, given limited agricultural resources like arable land, it will be a difficult task to increase the production and productivity of maize production for better food security.

In the literature, Technical Efficiency (TE) approach introduced by Farrell (1957) is used to explore the capacity of farmers to produce optimum quantity of output with the given level of inputs. Efficiency is a very important factor of productivity growth indicator for a resource constrained economy. The extent of inefficiency estimates also help to decide whether to improve efficiency or to develop new technologies to improve agricultural productivity in the country. Therefore, we can employ this efficiency approach to investigate the low productivity and production inefficiency growth in the smallholdermaize farmers in Bhutan. For smallholder Bhutanese maize farmers, variations in productivity due to differences in efficiency may be affected by various farm specific factors such as seed type, amount of fertilizer dose, farm size, family size, credit accessible to farmers, education level of household head, land type etc. The main purpose of this study is to analyze technical efficiency of maize farming in eastern region of Bhutan. Bhutanese productivity in maize production could be improved enhancing the production efficiency of smallholder farmers in the country. To increase production efficiency of smallholder maize farmers, more efficient use of inputs is critical. There are many factors that influence farmer's efficiency. Addulai et al. (2018) in Ghana found that maize production responded positively to increase in chemical fertilizers, seed quantity, the use of labor. They found mean technical efficiency of around 69%. Similarly, Belette (2020) in Ethiopia found that farm size, labour and access to chemical fertilizers, farm income, and credit accessibility to farmers were significant determinant of maize output. Socioeconomic factors that contribute to technical efficiency were sex, credit access, education, resource availability, farm size and years of experience in farming. Ng'ombe et al. (2014) examined factors influencing the technical efficiency of smallholder maize farmers in Zambia. They found mean technical efficiencies of around 79.6%, whereas credit accessibility, distance from the road, and extension services were important factors influencing technical efficiencies in the study area. The production inefficiencies are reducing maize productivity; the sources of such inefficiencies are diverse. Many factors contribute to low productivity, which include: farm management, resource use, inadequate knowledge of appropriate technology, in-adequate market price, socio-economic factors (Adhikari et al, 2018). This study therefore, aims to investigate the technical efficiency of small holder farmers and assess the determinants of technical efficiency in maize production.

2. METHODOLOGY

2.1 Study Site

Samdrup Jongkhar district is located in the Southeastern part of the country, sharing its southern border with Indian states of Assam and northern border with Arunachal Pradesh. District has record of 40, 766 population with 4808 households and an area of 1877.94 sg.km. The main crops produced in the district include maize, bucket, millet, rice. The study area has an average annual rainfall of 62.5 mm with humidity close to 58% (Samdrup Jongkhar Dzongkhag Statistics, 2022).

2.2The Model

The parametric stochastic frontier production function analysis is based on specific functional form and it includes random shocks which enables us to accommodate uncertainty of farmers under the study. Following Adhikari et al. (2018), the empirical Cobb-Douglas frontier production function model with double log form is given as:

$$Ln(yield) = \beta_0 + \beta_1(Land\ area) + \beta_2(Labor) + \beta_3(Oxen) + \beta_4(Seed) + \beta_5(Urea) + \varepsilon_i(V_i - U_i) \dots\dots\dots\dots.(i)$$

Where *Ln* is the natural logarithm, yield is the maize production per acre (Kg/ac), $\beta_0 - \beta_5$ are the parameters to be estimated. Land area is the area under maize cultivation (ac), labor is the total number of labors required per hour, oxen constitute the number of oxen owned, seed is the kg of maize seed per acre, urea is the amount of Nitrogenous fertilizer applied per acre (Kg/ac), V_i is two-sided random error component beyond the control of the farmer and U_i is the one-sided inefficiency component.

The farm specific technical efficiency (TE_i) of the *ith*sample farmer will be estimated by employing the expectation of U_i conditional on the random variable ε_i.

$$TE_i = EXP(-U_i)$$
$$= Y_i / f(X_i\beta) \exp V_i$$
$$= Y_i / Y^*$$

Where Y_i = Observed output, Y^* = Frontier output. If $Y_i = Y^*$ = then, TE_i = 1 implying 100% efficient. After obtaining the technical efficiency estimate, we will investigate socio-economic determinants of technical inefficiency of maize production.

3. RESULTS AND DISCUSSION

Table 1 describes the summary statistics of socio-economic characteristics of farm households and variables involved in the frontier production function analysis. The average age of household heads is 43, showing a relatively younger population. Years of experience in maize farming is between 19 and 42 years with an average of 36 years. The average family size is 15 persons, clear evidence of the rural nature of the household, with family labour as main source of labour.

Table 1. Household Descriptive Statistics

Variables	Mean	SD	Min.	Max.
Outputs				
Maize yield	5432	2761.6	2400	12300
Inputs				
Seed	23.54	4.23	16	44
land	0.56	0.75	0.98	5.54
Labour	25.43	7.09	8	20

Oxen	2.13	0.897	0	4
Fertilizers	80.11	121.14	25	460
Farm-specific factors				
Age	43	6.65	27	76
Experience	36	6.4	19	42
Farm size	2.08	6.23	2.02	5.04
Household size	3	2	2	12
Education	0.55	0.49	0	1
Training	0.84	0.36	0	1

Maize farms are of small size, 2.02 to 5.04 ac, with an average of 2.08 ac. The average output per cropping season is about 5432 kg/ac. The maize production is relatively small in the study area as compared to other districts owing to agricultural landscape of the district. On average, maize farmers applied 23.54 kg of seed, 80.11 kg of urea and allotted 0.56 acre of land for maize cultivation.

The maximum likelihood estimates of the stochastic frontier production function and the determining factors of technical efficiency are shown in Table 2. The coefficients of total maize land and amount of urea applied in maize output production are found to be positively significant at 5 % and 1 % respectively. The coefficient of oxen is found to be positive and significant in the maize production at 1 % level of significance. This may be attributed to the fact that most of the farmers rely still on traditional farming and less penetration of modern farm technology in the study area. Low technology adoption rate in maize production is also supported by the fact that both education and training factors are found to be statistically insignificant in the study area.

Seed used per acre is found to be negatively significant at 10 % level. It implies that a 10 % increase in seed rate, would lead to a 23% decrease in maize output. This is because of that high seed rates would result in higher maize plant density, which in turn results in high competition among the plants for the same small amount of nutrients and water at their localized area. A similar finding was concluded by Lema et al. (2018) and Addai et al. (2014).

Table 2. Socio-Economic Determinants of Inefficiency

Variables	Coefficient	Standard Error	P-value
Ln (Land)	0.061**	0.067	0.071
Ln (Labour)	0.007	0.101	0.763
Ln (Seed)	-0.235*	0.174	0.084
Ln (Fertilizer)	0.120***	0.023	0.005
Ln (Oxen)	0.015	0.167	0.812
Constant	6.02***	0.431	0.000
Technical Inefficiency Component			
Age	0.041*	0.026	0.079
Experience	-0.07*	0.51	0.064
Education	-0.0831	0.079	0.048
Farm size	-0.069**	0.024	0.047
Training	-6.471	6.142	0.523
Household size	-0.471**	0.856	0.038
Constant	-0.915***	2.673	0.679
Log likelihood	1.26847		
Prob>chi^2	0.0000		
No. of obs.	120		
Wald chi^2	95.6		

Note ***Significant at 1% significance level; **significant at 5% significance level * Significant at 10% significance level

The socio-economic factors including age of the household head, experience of maize farming, household size, farm size, education of household head, off farm income and dummy variables training received related to maize farming which influences the efficiency of maize production are represented in Table 2. Except the age factor, all other determinants have a negative coefficient. The positive coefficient of age factor implies that it positively influences the technical inefficiency of maize output. The younger the age of maize farmers, the more efficient the farmers in maize production. This can be attributed to young farmers more receptive, better knowledge and management skills of maize production as compared with other older farmers. This finding is consistent with the study by Adhikari et al. (2018). The coefficient of household size is found to be negative and statistically significant. This implies that a larger household size has a positive impact on maize efficiency. This could be due to the fact that a larger the size of household provides a more resources in terms of farm household labour in maize output production. The study also identifies that other influencing factor like education of the household, farm land holding, training received by the farmers in terms of maize production have all negative coefficients, implying that all those factors have a positive impact on maize efficiency. A similar finding was concluded in the study by Payang et al. (2019).

The economic efficiency level is between 20.13 and 94.75, with an average of 78.19 % (Table 3). This result indicates that there is clear evidence of potential reduction of the costs of maize production while holding the same level of production by improving technical efficiency. There is a possibility of reduction of economic cost of production by almost 25 % by the maize producers in the study area.Maize farmers can increase their productivity of maize production if they can reduce cost of production and raise technical efficiency of maize output.

Table 3. Economic Efficiency

	N	Mean	SD	Min.	Max.
Economic Efficiency (%)	120	78.19	13.07	20.13	94.75
N valid (list-wise)	120				

Table 4 depicts distribution of technical efficiency score of the maize farmers in the study area. The efficiency score results reveal that technical efficiency of maize farmers ranges from 38.89 % to 97.35 % with an average score of 81.47 %. This applies that technical efficiency of maize farmers in the study area could be increased by 18.53 %. Majority (41%) of farmers are producing technically efficient maize output, however they can still improve their productivity by 18% to realize the full potential of maize production in the study area.

Table 4. Technical Efficiency of Maize Farmers

Efficiency Level	Frequency	% of Farmers
0<TE<20	0	0
20<TE<30	0	0
30<TE<40	2	1.6
40<TE<50	4	4.8
50<TE<60	11	9.1
60<TE<70	20	16.6
70<TE<80	32	26.6
80<TE<90	41	34.1
90<TE<100	10	8.3
Mean TE	81.47%	
Standard Deviation	14.87%	
Minimum	38.89%	
Maximum	97.35%	

4. CONCLUSION

This study was conducted mainly to analyzed the technical efficiency and assess the factors affecting the technical efficiency of maize production in Samdrup District. The study shows that the average technical efficiency score was around 81.47 % with a minimum score of 38.89 % and a maximum of 97.35 %. This proved that there was substantial possibility to increase maize yield in the study area by improving resource use efficiency. The main factors affecting the technical efficiency of rice farmers in the study area included experience, education, training, use of urea, and household size. To improve the technical efficiency of maize farming in the study area, the following policy implications should be considered. The study recommends the provision of more trainings on adoption of better modern varieties of maize yield, and also provide subsidies on provision of agrochemical fertilizers like urea in the study area.

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