Original Research Article

Analysis of the Technical Efficiency of Rice Production in Radhi Gewog, Trashigang District, Bhutan: A Stochastic Frontier Approach

ABSTRACT

Rice is the staple cereal crop in Bhutan. This paper analyzes the technical efficiency and its associated factors that influences the rice efficiency in Radhi Gewog, Trashigang District in Eastern Bhutan. Primary data on socio-economic and production function data were collected by employing stratified random sampling from 120 rice producing farmers for the year 2021-2022. The stochastic frontier parametric analysis approach was used for analyzing the objective of the paper. The results showed that rice farmers in the study area are technically efficiency at 76.4 percent. Training, size of the household and extension were found to have significant effect on maize technical efficiency.

Keywords:Production, Parametric, Output, Technical Efficiency, Yield.

1. INTRODUCTION

Agriculture sector contributes about 20 per cent towards the gross domestic product of the Bhutanese economy. Rice is the main staple food in the country and attaining the rice self-sufficiency has always been the top priority in the agricultural policy agenda. The total area under rice cultivation was 31,455.40 acres with 53,360.93 MT of rice production in 2020 (MoAF 2021). Rice is grown in about 31,455 ac (DoA 2021) with a total production of about 65,763 MT of rice. In 2020, rice yield for Bhutan was 42, 643 hg per ha. Rice yield of Bhutan increased from 20,000 hg per ha I 1971 to 42,643 hg per ha in 2020 (DoA 2021). Despite the positive trend in average annual rice yield it is not able to meet its own domestic rice consumption demand.

Therefore, yield per hectare of rice plays a crucial role in increasing the production of rice crop to cope with the increasing demand for food of rapidly expanding population. In order to cope with these challenges, it is required that the factors which are responsible for low yield should be taken care of. One of the major factors in considered to be the low productive efficiency, which is also called technical efficiency. Hence, the study at hand will be the first study of its kind which will investigate the technical efficiency of rice farmers and identify the factors which affect the efficiency. It is hoped that the results of this study would be of great interest for the policy makers and planner to devise the policies that will in turn raise yield per hectare of rice through appropriate and efficient use of available resources.

Aim of the Study

The main aim of this study is to measure technical efficiency and identify those determinants that influences the resulting inefficiency levels.

Objectives of the Study

The main objectives of this paper is:

- To provide baseline information about the level of farming inefficiency in the study area by estimating technical inefficiency score in rice production.
- To examine the determinants of technical inefficiency in rice production.

The economic theory of production provides the analytical framework for most empirical research on productivity and efficiency. In general parlance, efficiency means the realization of a production goal without waste. Beginning with this basic idea of “no waste”, economists have built up a variety of theories of efficiency. The basic idea underlying all efficiency measures, however, is that of the quantity of goods and services per unit of input. Accordingly, a production unit is said to be technically inefficient if too little output is being produced from a given bundle of inputs.The economic theory of production provides the analytical framework for most empirical research on productivity and efficiency. In general parlance, efficiency means the realization of a production goal without waste. Beginning with this basic idea of "no waste", economists have built up a variety of theories of efficiency. The basic idea underlying all efficiency measures, however, is that of the quantity of goods and services per unit of input. Accordingly, a production unit is said to be technically inefficient if too little output is being produced from a given bundle of inputs. Technical efficiency (TE) refers to the ability of a Decision-Making Unit (DMU) to produce the maximum feasible output from a given bundle of inputs, or the minimum feasible amounts of inputs to produce a given level of output (Farrel 1957). Farrell argued that the firm's efficiency can be calculated empirically and he proposed, for the first time, an innovation method of efficiency frontier estimation from real situations of production.

There are two primary methods of efficiency measures, namely stochastic frontiers and data envelopment analysis (DEA), which involve econometric methods and mathematical programming, respectively. Stochastic frontier models make assumptions about the functional form of production or cost functions, and can deal effectively with the presence of noise in the data, whereas DEA models make no assumptions about the functional forms, but cannot deal effectively with measurement error (Tsionas et al.., 2003). Coelli (1995) recommended the stochastic frontier method for use in most agricultural applications, and also pointed out that the stochastic frontier model has the added advantage of the ability to conduct statistical tests of hypotheses regarding the production structure and the degree of inefficiency. Therefore, the stochastic frontier model is more suitable than DEA in this study. The Stochastic frontier model (SFM) is usually used to measure technical efficiency or inefficiency scores for each individual. It was proposed independently by Aigner et al. (1997) and Meeusen and Broeck (1997). This method has been widely used in many research fields for technical efficiency analysis, particularly in agricultural economics. For example, Chen and Song (2008) used the stochastic frontier model to examine technical efficiency and the technology gap in China's agriculture. Rahman et al.., (2012) applied stochastic frontier model to model the technical efficiency of rice farmers in Bangladesh. Yang et al.., (2016) investigated the presence of production risk and technical inefficiency for a sample of rice farms in the Xiangyang City of China using a stochastic production frontier framework. Kim et al.., (2016) utilized the stochastic production frontier model to examine productivity of inputs for small and medium farmers in korea. Bamlaku et al.., (2007) have analyzed technical efficiency of farmers in three ecological zones in Ethiopia. Access to credit, literacy, proximity to market, and livestock are found to have positive and significant effect, while age, sex, extension service, and off farm activities are found to have insignificant effect on technical efficiency of farmers. Moreover, Endrias et al.., (2012) have examined technical efficiency of maize farmers in Ethiopia. Based on their estimation, agro-ecology, oxen holding, farm size, and use of improved maize variety are found to be significant, whereas age, education, family size, and access to credit are found to be insignificant determinants of technical efficiency.

However, in the context of Bhutan, there is no study that compare the technical efficiency of rice production and identify the common and specific characteristics which influence its technical efficiency. Consequently, this paper contributes to fill the current gap by estimating technical efficiency and identify the common and specific characteristics which contribute to the technical efficiency of Bhutanese rice sector.

2. METHODOLOGY

2.1. Study Site

The study will be carried out in Radhi Gewog under Trashigang District. Radhi Geog is located in north of Trashigang district located on a gentle slope of terraced paddy fields. Gewog is considered as the most profuse rice producing Geog in Trashigang district. The Gewog produces one of the largest quantities of rice in the east and is considered the rice bowl of the east. According to statistics with the dzongkhag agriculture sector, Radhi Gewog produced 2,553.59MT of rice in 2017-2018 from 1,236.16 acres of wetland. In Radhi, rice is grown from the altitude of 1250 meters-1,900-meters (Tashi et al., 2021).

2.2. Sampling

Aligned with the objective of study, approach is undertaken to estimate technical efficiency and identify the factors that influences the resulting inefficiency levels in the rice production. Four Chiwogs will be selected after consultation with Dzongkhag officials. The household (24) from each Chiwog/Unit will be selected through Probability Proportionate Sampling (PPS) to provide equal representation of 120 sample. The information will be collected using structured questionnaires. Attention will be paid to keep the questionnaire simple and concise to avoid any confusion and ambiguity. And finally questionnaire will be translated into local language to make local reader and enumerator understand the question and objective clearly. Further, interviewers will be trained before sending them to field for the data collection. The study is expected to cover 80 percent of the household from four Chiwogs. The data will be coded and will be entered using Statistical Package for Social Science (SPSS).

Comment [E1]: Where is the sample frame?

2.3. Empirical Model

Technical Efficiency is defined as the ability of a decision-making unit (farm in our study) to produce maximum output given a set of inputs and technology. For this study purpose, we employed the following stochastic frontier production function:

$$\ln y_i = \ln \beta_0 + \sum_{j=1}^{9} \beta_j \ln x_{ij} + \varepsilon_i,\ i = 1, 2, .., ...(1)$$

Where i stands for i^{th} farm and j stands for j^{th} input and β_0, β_j denotes intercept. y_i represents output of rice for the i^{th} farm, x_{ij} is a vector of k inputs and the detail of independent variables is summarized as below;

X_{i1} = Quantity of rice produced (kg/ac)

X_{i2} = Plowing hours/farm

X_{i3} = Irrigation (numbers per acre)

X_{i4} = Labor hours/farm

X_{i5} = Plant protection chemicals (litres/ac)

X_{i6} = Quantity of fertilizers NPK (kg/ac)

X_{i7} = Quantity of manure (kg/ac)

X_{i8} = Quantity of seed (kg/ac)

X_{i9} = Machine labor (Hours/ac)

X_{i10}= No. of cattle owned

The technical inefficiency effect can be expressed in the following general form:

$$u_i = \delta_0 + \sum_{k=1}^{n} \delta_k z_{ki} + \omega_{ki}.............(2)$$

Where ω_{ki} is the statistical noises; z_{ki} denotes exogenous variables (years of experience as farmer, disaster, distant to Gewog RNR extension, agriculture policy, age of the household head, gender of the household head, education qualification of the household head, access to credit, land size owned, distance from home to farm) that are factors affecting rice production TE; δ_0 and δ_k are estimated coefficients; the sign of δ_k determines the relationship between affecting factors variables and the TE of rice production.

Followed by equation (1) and (2), the parameters estimation of SFA model can be achieved by applying maximum likelihood estimation method, which estimates the likelihood function in terms of two variance parameters (Coelli 2005)

$$\gamma = \sigma_u^2 / \sigma_s^2; \quad \sigma_s^2 = \sigma_v^2 + \sigma_u^2.............(3)$$

Gamma (γ) takes value between zero and one, reflects validity of the random disturbances (v_i, u_i proportion. If (γ)is closer to zero, it indicates that the gap between actual output and the maximum possible output mainly comes from other uncontrolled pure random factors, which makes the use of stochastic frontier model meaningless. In contrast, if (γ) is closer to one, it shows that the gap comes mainly from the effects of one or more exogenous variables z_{ki} indicates using stochastic frontier production function model is more appropriate.

3. RESULTS AND DISCUSSION

The study was conducted to investigate the technical efficiency of rice farmers in Radhi Gewog under Trashigang District. Summary statistics of variables used in the frontier production function is shown in Table 1. The average rice output was 5432 kg per acre with a minimum of 2400 per acre production. Generation of rice output involves average labor involvement of 15.43 including both family and hired labor. The number of oxen owned by farm household varied from 0 to 4 with an average of 2.13. Rice farmers applied on an average 80.11 kg of fertilizers per acre. Approximately 34 percent of the farmers resort to use of manure for the rice production.

Table 1.Summary of the Frontier Production Function

Variables	Unit	Mean	SD	Min.	Max.

Comment [E2]: Do you mean water provision?

Comment [E3]:

Rice yield	kg/ac	5432	2761.6	2400	12300
Seed	kg	23.54	4.23	16	44
land	ac	0.56	0.75	0.98	5.54
Labor	no.	15.43	7.09	8	20
Oxen	no.	2.13	0.897	0	4
Fertilizers	kg/ac	80.11	121.14	25	460
Manure	dummy	0.34	0.36	0	1

Table 2 presents the summary statistics of the socio-economic characteristics of rice producing households. The mean age of the rice farmers was 43 with minimum of 27 and maximum of 76 age. The mean size of the farm household was 3.74 with the 2 and 9 being the minimum and maximum household size respectively. Majority (74%) of the rice farming household responded training received from the Gewog Agriculture Extension office.

Table 2: Summary Statistics of Socio-Economic Characteristics of Respondents

Variables	Mean	SD	Min.	Max.
Age	43	6.65	27	76
Experience	36	6.4	19	42
Farm size	2.08	6.23	1.02	5.04
Extension	3	2	2	12
Education	0.55	0.49	0	1
Household size	3.74	2.02	2	9
Training	0.74	0.36	0	1

Ordinary least square estimates of the log linear Cobb-Douglas production function are shown in Table 3. As shown in the table, factor inputs like land size, number of oxen owned and labor force employed in rice farming were found to be positive and significant in the production process at 1 percent level of significance.

Table 3: Ordinary Least Square Estimates of the Cobb-Douglas Production Function

Rice output	Coef.	Std. Err.	t	P > |t|
Intercept	4.175***	0.246	10.23	0.000
Land	0.146***	0.036	4.23	0.001
Seed	0.164*	0.076	2.15	0.051
Labor	1.024***	0.042	9.58	0.000
Oxen	0.152***	0.036	7.59	0.000
Fertilizer	0.102*	0.072	1.83	0.076
Manure	0.042	0.035	2.34	0.000
R squared	0.794			
Adjusted R squared	0.789			
No. of obs.	120			

Note: The asterisks (*, **, ***) indicates significance at the 10%, 5%, and 1%le levels.

On the other hand, fertilizer and rice seed applied were found to have a positive and significant effect on rice output at 10 percent level of significance. The application of manure to rice production was found to be insignificant and it had a negligible role to rice production in the study area. A model implied a goodness of fit for the regression with a higher R and Adjusted R with 79.4 and 78.9 percent respectively.

Table 4: Parameter Estimates of the Stochastic Frontier Model

Variables	Coef.	Std. Err.	t	P > |t|
Intercept	4.175***	0.246	10.23	0.000
Land	0.146***	0.036	4.23	0.001

Comment [E4]: The SD is wide. Check the data if there are outliers, please.

Comment [E5]: Check the Methodology, you have given its measurement as Kg/ac. So it is not Dummy

Comment [E6]: 4.056

Comment [E7]: Correct

Comment [E8]: 24.38

Comment [E9]: 4.22

Comment [E10]: This T-value is 1.200 not 2.34. Check please.

Comment [E11]: Not in the Table

Seed	0.164*	0.076	2.15	0.051
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The elasticities of the independent variables are provided in Table 5. As can be seen from the table, the elasticity of labor was found to be higher, implying that rice yield was more responsive to the amount of labor employed in the production process. The response of rice yield was significant to the rest of the covariates involved in the Cobb-Douglass stochastic frontier model.

Table 5: Elasticities of Independent Variables

Variables	Elasticities	Std. Err	z	P |z|
Land	0.012	0.002	2.32	0.00
Labor	0.241	0.023	10.23	0.00
Seed	0.063	0.027	2.04	0.04
Oxen	0.024	0.003	4.53	0.00
Fertilizer	0.043	0.013	3.45	0.03

Technical efficiency scores of rice producing farmers are presented in Table 6. It was evident from the result that total technical efficiency scores ranged from 28.87 percent to 94.32 percent with a mean score of 76.4 percent. Thus, based on the efficiency theory, a rice farmer operating at full efficiency level could reduce its input use, on average, by 23.6 percent to produce the same level of rice output.

Table 6: Technical Efficiency Distribution of Rice Farmers

TE Rating (%)		No. of Farmers	Age of Farmers (%)
0<TE<20		0	0
20<TE<30		1	0.8
30<TE<40		3	2.5
40<TE<50		5	4.1
50<TE<60		14	11.6
60<TE<70		20	16.6
70<TE<80		29	24.1
80<TE<90		32	26.6
90<TE<100		16	13.3
Mean TE	76.4%		
Standard deviation	12.675		
Minimum	28.87%		
Maximum	94.32		

4. CONCLUSION

This study analyzed the technical efficiency of rice production in Radhi Gewog under Trashigang District. The result revealed that the mean technical efficiency score was around 76.4 percent with a minimum score of 28.87 and maximum of 94.32 percent. This proved that there was substantial possibility to increase rice yield in the study area by improving resource use efficiency. The main determinants affecting rice efficiency in the study area includes extension service, training, experience of the rice farming. Thus, it is recommended that supply of better agrochemicals, and provision of better trainings and skill development are essential for the rice producers in the study area.

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