



# Technical Efficiency Analysis of Pineapple Production at Madhupur Upazila of Tangail District, Bangladesh

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## Authors' contributions

This work was carried out in collaboration among all authors. Author KA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author SM managed the analyses, supervised and edited the work. Author MAI reviewed the analysis and all drafts of the manuscript. Author BS managed the literature searches. All authors read and approved the final manuscript.

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## ABSTRACT

The main objective of this study is to analyse the technical efficiency and its determinants of pineapple production at Madhupur upazila of Tangail district in Bangladesh. Cross-section data from a sample of 100 pineapple producers during the 2016-17 cropping season were collected by applying multistage random sampling technique. Farm specific technical efficiency scores were estimated using the Cobb-Douglas stochastic frontier production function approach. Empirical findings show that the estimated technical efficiencies of the sampled farmers' range from 61.61% to 99.95% with the mean technical efficiency of 91.14%. The result suggests that, on an average, farmers in the study area can potentially increase their productivity by 8.86% through more efficient use of inputs. The estimated stochastic production frontier model indicates that input variables such as area, tillage cost, seedling cost and human labour cost were statistically significant

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variables to increase the quantity of pineapple production. Technical inefficiency effect model identifies that age of farmers had significant positive, but years of schooling and extension contact had significant negative effect on farmers' inefficiency. The study therefore recommends that government should focus on the ways of attracting and encouraging the youths as they are more efficient and are likely to be able to properly allocate resources and are willing to adopt new technical innovations. Besides, policies and strategies should be directed towards increasing farmers' formal as well as informal education through the implementation of effective training programmes by the well-trained extension workers.

**Keywords:** *Pineapple; technical efficiency; Cobb-Douglas stochastic production frontier model; Tangail district.*

## 1. INTRODUCTION

Agriculture is one of the most important economic sectors in Bangladesh, as it contributes about 11.70% to the country's Gross Domestic Product (GDP) and employs around 42.7% of the labor force [1]. According to [2], in 1972, agriculture contributed around 52% of total GDP of this country. When industrialization started the activities of the population started diversification towards different sectors. Over a period of time, the rate of contribution in national GDP of agriculture has been decreasing gradually [3]. Bangladesh is also one of the most densely populated nations of the world (964 persons per Km<sup>2</sup>) with an estimated population of 142.3 million, of which 75% live in rural areas [4]. The nation also suffers from one of the lowest land-man ratios of the world (0.2 ha per person), making it very difficult to achieve food security [5]. As the country's agriculture has already been operating at its land frontier, there is little or no scope to expand cultivable land to meet increasing demand for food [6]. Given these situations, agricultural productivity growth and efficiency improvement remain a top priority for Bangladesh in order to meet food needs for its rapidly increasing population. Agricultural productivity can increase either through introduction of modern technologies or by improving the efficiency of inputs with existing technologies [7]. However, in an economy like Bangladesh where resources are scarce and opportunities for new technologies are lacking, considerable efforts have been devoted to the analysis of technical efficiency that will be able to show the possibilities to raise productivity by improving efficiency of farms without increasing the resource base or developing new technology. Thus, technical efficiency is the ability of a farm to produce a given level of output with a minimum quantity of inputs under a given technology [8].

Fruits play a vital role in the overall economic performance of Bangladesh. The production of fruits of this country is increasing day by day. Among all the fruits produced in the country, pineapple ranks 4<sup>th</sup> in terms of total cropping area and production [9]. Pineapple (*Ananas comosus*) is one of the most leading commercial fruits in the world because of its exclusive flavour, pleasant aroma, deliciousness, nutritional and medicinal values [10]. It is the third most important tropical fruit in the world after Banana and Citrus [11]. It contains considerable amount of calcium, potassium, vitamin C, carbohydrates, crude fibre, water and different minerals that are good for the digestive system and helps in maintaining ideal body weight and balanced nutrition [12]. The tropical climate is better for pineapple cultivation. Although Bangladesh is not a tropical country, the climate and the soils of many parts of Bangladesh are much more suitable for pineapple production [9]. It is widely cultivated in Tangail, Mymensingh, Gazipur, Sylhet, Moulvibazar, Chattagram, Bandarban, Khagrachari and Rangamati districts. At least ninety varieties of pineapple are cultivated in the world. In Bangladesh, three varieties of pineapple are mostly grown. The cultivated varieties are Giant Kew, Honey Queen, and Ghorasal [13]. Bangladesh produces 200701 metric tonnes of pineapple from 13556 hectares of land during 2015-16 cropping season. However, Tangail is the largest pineapple producing district in Bangladesh covers about 50% of the total pineapple production per year. About 6191 hectares of land of this district are under pineapple cultivation with a total production of about 108023 metric tonnes [1]. Total area and production of pineapple have increased steadily during the last decades. But, productivity of pineapple in Bangladesh is low compared to other pineapple producing countries of the world. The average productivity of pineapple of this country is about 14 mt/ha per

annum [1], which is quite low compared to the neighbouring country India where average productivity of pineapple is above 17 mt/ha per annum [14]. There is much scope of increasing its production by the enhancement of productivity under existing technologies [15].

A large number of studies on farm productivity and technical efficiency of different agricultural products were conducted in Bangladesh. Notably, [16] carried out a study to measure food security through increasing technical efficiency and reducing postharvest losses of rice production systems in Bangladesh. [17] measured productivity and efficiency of potato production in Aditmari and Lalmonirhat Sadar of Lalmonirhat district using trans-log stochastic frontier analysis. Moreover, limited studies have also been done regarding area, production, yield, nutritional value and problems of pineapple under different zones of Bangladesh. [13] conducted a study on pineapple production status in Bangladesh to discuss about the area, production, yield and importance of pineapple in the country. Another study was conducted by [9] to determine the impact of pineapple cultivation on the income of pineapple growers of Madhupur upazila under Tangail District. But no study has been conducted in the area of technical efficiency of pineapple production in this country. The present study is an endeavor to fulfill this gap in the literature. Therefore, the main objective of this study is to estimate technical efficiency and determine the factors affecting the technical inefficiencies of pineapple production in the study area. It is expected that the findings of this study will be useful and accurate which can facilitate policy makers, planners, researchers, and stakeholders in understanding factors those are needed to be taken into care for the improvement of pineapple production in the country.

## 2. MATERIALS AND METHODS

### 2.1 Theoretical Framework

According to Farrell MJ [18], technical efficiency (TE) is defined as the ability of a farm to attain the optimal production of output for a given set of inputs (an output orientation) or, alternatively, as the measure of the ability of a farm to use the minimum possible amount of inputs to produce a given level of production (an input orientation). Therefore, a technically efficient producer could use the same input to produce more of at least one output or could produce the same output

with less of at least one input. As a result, 'technical inefficiency' means the failure of firm to attain the highest possible level of output given inputs and technologies. Stochastic frontier production function was used to analyze the technical efficiency of the pineapple farmers in the study area. The stochastic frontier production function was independently proposed by [19] and [20] which can therefore be written as;

$$Y_i = f(X_{ij}, \beta) + \varepsilon_i \quad i = 1, 2, \dots, N \quad (1)$$

where,  $Y_i$  is the scalar output of the  $i^{\text{th}}$  farm;  $X_{ij}$  is a vector of quantity of  $j^{\text{th}}$  inputs applied to  $i^{\text{th}}$  farm,  $\beta$  is a vector of parameters to be estimated and  $f(\cdot)$  is a suitable production function and  $\varepsilon_i$  is the error term that is composed of two independent components  $V_i$  and  $U_i$ , such that  $\varepsilon_i = V_i - U_i$ . The random (symmetric) component  $V_i$  is assumed to be identically and independently distributed as  $N(0, \sigma_v^2)$  and is also independent of  $U_i$ . This random error represents random variations in output due to factors outside the control of the farmers reflecting luck, weather, natural disaster, machine breakdown and variable input quality as well as the effects of measurement errors in the output variable, statistical noise and omitted variables from the functional form. According to [21],  $U_i$  is nonnegative random variable that represents the stochastic shortfall of outputs from the most efficient production. Therefore,  $U_i$  is associated with the technical inefficiency of the farmers and are assumed to be independently and identically distributed truncations of the half normal distribution as  $N(0, \sigma_u^2)$ . The mean of the distribution of  $U_i$  is assumed to be a function of a set of explanatory variables:  $\mu_i = \delta_i Z_i$ , the inefficiency term is:

$$U_i = \sum_{j=1}^n \delta_j Z_{ij} + w_i \quad (2)$$

where,  $Z_{ij}$  is a vector of the farm specific variables that are assumed to influence  $U_i$ ,  $\delta_i$  is a vector of parameters to be estimated, and  $w_i$ 's are random error that are defined by the truncation of the normal distribution with zero mean and variance,  $\sigma_w^2$ , such that the point of truncation is  $-Z_i \delta$ , i.e.,  $w_i > -Z_i \delta$ . These assumptions are consistent with  $U_i$  being a non-negative truncation of the  $N(Z_i \delta, \sigma_u^2)$ -distribution. The parameters of the stochastic frontier model can be estimated by the maximum-likelihood estimation method using the computer program FRONTIER Version 4.1 [22]. The variance of the parameters of the likelihood function are estimated as;

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \text{ and } \gamma = \frac{\sigma_u^2}{\sigma^2} \text{ So that } 0 \leq \gamma \leq 1 \quad (3)$$

The value of the  $\gamma$  parameter lies between 0 and 1 and determines the presence or absence of technical inefficiency. If  $\gamma = 0$  indicates that the  $U_i$  is absent in the model. However, if  $\gamma = 1$  it denotes that all deviations from the production frontier are exclusively a result of technical inefficiency [23]. Therefore, the technical efficiency (TE) of an individual farm can be defined in terms of the ratio of the observed output to the corresponding frontier output, given the available technology. Hence, the technical efficiency of the farmer is expressed as;

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{\{f(X_i, \beta) \cdot \exp(V_i - U_i)\}}{\{f(X_i, \beta) \cdot \exp(V_i)\}} = \exp(-U_i) \quad (4)$$

where,  $Y_i$  denotes observed output of  $i^{\text{th}}$  farm for given input level and technology,  $Y_i^*$  denotes the maximum attainable or production frontier output of  $i^{\text{th}}$  farm at the same input level and technology,  $Y_i$  achieves its maximum feasible value of  $f(X_i, \beta) \cdot \exp(V_i)$  if, and only if  $TE_i = 1$ . Otherwise  $TE_i < 1$  provides a measure of the shortfall of observed output from maximum feasible output in an environment characterized by  $\exp(V_i)$ , which is allowed to vary across producers [24].

## 2.2 Study Area and Method of Data Collection

Based on the intensity of pineapple production, agroecology and accessibility, Tangail district has been selected purposively. It is the largest pineapple producing district of Bangladesh. About 50% of the total pineapple production of Bangladesh came from this district [1]. There are twelve upazilas under Tangail district but pineapple is cultivated in three upazilas only. They are namely; Madhupur upazila, Ghatail upazila and Shakhipur upazila. Madhupur is the largest pineapple producing upazila, contributing about 85% of the total production of pineapple of this district [25]. So, on the basis of higher concentration of pineapple production, Madhupur upazila of Tangail district has been selected as the study area. The primary data were collected in a field survey by direct interview with pineapple farmers in the study area during the 2016-2017 cropping season. Respondents' selections were made using the multistage random sampling procedure. At the first stage, simple random sampling technique was used in

selecting two unions out of the six unions. These unions were Ausnara union and Aronkhola union. At the second stage, five villages were selected randomly from each union. Five villages namely, Ausnara, Idilpur, Mohismara, Bokerbaid, Holudia of Ausnara union and five villages namely, Jolsotro, Kakraid, Chunia, Danokbandha, Gubudia of Aronkhola union have been selected randomly for the study. Finally, the third stage involved random selection of 10 pineapple producers from each village who were at the initial stage of cultivation (i.e., harvested first yield from their pineapple fields), giving a total sample size of 100 farmers.

## 2.3 Empirical Model Specification

Various functional forms may be specified for the stochastic frontier production functions, viz. linear, Cobb-Douglas, constant elasticity of substitution, trans-log, quadratic, etc. Among them, Cobb-Douglas and trans-log are most popular. In the present study a test was conducted that was used by [26] for the selection of functional form, i.e., whether to fit a Cobb-Douglas or trans-log type model for production frontier. For model selection, the null hypothesis to be tested was "the frontier is Cobb-Douglas form, that is, all the effects of interaction and square terms in the trans-log (non-homothetic) model is equal to zero, i.e.  $\beta_{jk} = 0$ ;  $j, k = 1, 2, \dots, n$  (when  $j = k$ ,  $\beta_{jk}$ 's represent the effects of square terms and when  $j \neq k$ ,  $\beta_{jk}$ 's represent the effects of interaction terms)". The above hypothesis was tested using the likelihood ratio test statistic which is defined as;

$$\lambda = -2 \{ \ln [L(H_0)] - \ln [L(H_1)] \} \quad (5)$$

where,  $L(H_0)$  and  $L(H_1)$  denote the log likelihood value of the Cobb-Douglas and trans-log models respectively. The test statistic  $\lambda$  had an approximately chi-square distribution with degrees of freedom equal to the difference between the number of parameters involved in  $H_0$  and  $H_1$  [16]. The first row of Table 3 reports this test, where the first null hypothesis is accepted showing that Cobb-Douglas stochastic production frontier model is appropriate for fitting the pineapple production data. The specified Cobb-Douglas stochastic production frontier model which is given by;

$$\ln Y_i = \beta_0 + \sum_{j=1}^6 \beta_j \ln X_{ji} + \phi_1 D_{1i} + \phi_2 D_{2i} + V_i - U_i \quad (6)$$

where,  $Y_i$  represents the return from pineapple production of  $i^{\text{th}}$  farm (in tk.);  $X_{1i}$  is the total area under pineapple cultivation (in hectare);  $X_{2i}$  is the tillage cost (in tk.);  $X_{3i}$  is the seedling cost (in tk.);  $X_{4i}$  is the fertilizer cost (in tk.);  $X_{5i}$  is the hormone cost (in tk.);  $X_{6i}$  is the total human labour cost (in tk.) by family and hired labourers in growing and harvesting of pineapple;  $D_{1i}$  is a dummy variable for variety which takes value one, if the variety is Giant kew and zero, otherwise;  $D_{2i}$  is a dummy variable for cropping pattern which takes one if follow intercropping system and zero, otherwise;  $\beta_0, \beta_j$ 's, and  $\phi$ 's are the unknown parameters to be estimated  $V_i$ 's and  $U_i$ 's are as explained above, that is  $V_i \sim \text{iid } N(0, \sigma_v^2)$  and  $U_i \sim \text{iid } N^+(Z_i\delta, \sigma_u^2)$ .

The technical inefficiency effects are linearly related to the farmers' characteristics. The model for the technical inefficiency effects in the stochastic frontier of equation (6) is defined as follows:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + w_i \quad (7)$$

where,  $Z_{1i}$  is the age of the pineapple farmer (in years);  $Z_{2i}$  is the education of the pineapple farmer (in years of schooling);  $Z_{3i}$  is the dummy variable for member of cooperative society (1 for yes and 0, otherwise);  $Z_{4i}$  is the dummy variable for micro finance taken from any source (e.g., relatives, friends, NGOs, Banks, etc.) only for cultivating pineapple (1 for yes and 0, otherwise);  $Z_{5i}$  is the dummy variable for extension service received by the pineapple farmer (1 for yes and 0, otherwise);  $Z_{6i}$  is the dummy variable for training on pineapple farming participated by the pineapple farmer (1 for yes and 0, otherwise); and  $w_i$ 's are random error that are defined by the truncation of the normal distribution with zero mean and variance,  $\sigma_w^2$ , such that the point of truncation is  $-Z_i\delta$ , i.e.,  $w_i > -Z_i\delta$ . These assumptions are consistent with  $U_i$  being a non-negative truncation of the  $N(Z_i\delta, \sigma_u^2)$ -distribution.

It is worth mentioning here that the above model for the inefficiency effects can only be estimated if the inefficiency effects are stochastic and have a particular distributional specification. Hence, the need arises to test the following null hypotheses:

- (i)  $H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$  i.e., farmers are completely efficient for producing pineapple.

- (ii)  $H_0: \gamma = 0$ , i.e., the inefficiency effects are not stochastic.

- (iii)  $H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ , i.e., the coefficients of the variables in the inefficiency effect model are not simultaneously equal to zero.

The tests of these hypotheses for the parameters of the frontier are conducted using the generalized likelihood ratio test which is explained above. All the tests of hypotheses were conducted at the 5% level of significance. The critical value of the test statistic was taken from [27]. If the calculated value of the test statistic is greater than or equal to its corresponding critical value, the null hypothesis was rejected.

### 3. RESULTS AND DISCUSSION

#### 3.1 Data Description

In the present study, data on output and inputs are used to estimate farm level technical efficiency of pineapple production. Before estimation, some properties of data such as mean, standard deviation are calculated. From Table 1, it is shown that the average area under pineapple cultivation among the farmers is 0.71 hectare. The mean return of the pineapple farmers is Tk. 468404.93 per hectare. The mean land rent incurred by the pineapple farmers is Tk. 82956.43 per hectare for 2016-17 cropping season. In the present study, rent per hectare is the amount of lease value required to be paid by a farmer for the two years production period. The average tillage cost of the farmers under the study area is Tk. 9492.53 per hectare. Most of the farmers had used power tiller to perform tillage operation. The average seedling cost is Tk. 54684.01 per hectare. The average manure and fertilizer cost are Tk. 3235.37 per hectare and Tk. 65911.08 per hectare respectively. Very small percentage of farmers used manure in their cultivation. The fertilizers used for the production include; Urea, TSP (Triple Super Phosphate) and MP (Muirate of Potash). In addition to these three fertilizers some farmers have used Gypsum, Boron, Roton, Zinc, Sulfur, etc. in their production. Farmers were not able to provide information on the quantity of fertilizers. They were only concerned with the amount of money required to purchase these fertilizers. So, fertilizer costs are used for necessary calculations. Average hormone cost is Tk. 8145.06 per hectare. Average labour cost is Tk. 88329.75 per hectare. The information on per

hectare man-days requirement was not available because all of the farmers used contractual agreement for this purpose. Lastly, the average total cost of pineapple production is Tk. 374904.15 per hectare.

### 3.2 Empirical Results of the Stochastic Production Frontier Model

The maximum likelihood estimates (MLE) of the parameters in the Cobb-Douglas production frontier model for pineapple are presented in Table 2. The coefficient of area under pineapple crop is positive and statistically significant at 1% level. This implies that there is a scope for increasing pineapple production with expected increase of 0.28% for a 1% increase in crop area. The finding is also supported by the study of [28] where area under pineapple cultivation

had positive significant effect on production. A greater investment in tillage would increase pineapple production as the coefficient is significantly positive and the average increase in production being 0.03% for a 1% increase in tillage cost. [29] also reported the positive effect of power tiller cost on pineapple production. The positive and significant coefficient of seedling cost also shows that there is a scope for increasing the productivity of 0.27% for 1% increase in seedling cost. [30] also reported significant positive effect of seedling cost on pineapple production. Production of pineapple could be increased by increasing human labour cost as the coefficient is significantly positive, the average increase being 0.34% for a 1% increase in human labour cost. Similar findings have been reported by several researches [31,32, 33].

**Table 1. Summary statistics of the variables used in the stochastic frontier model**

Items	Mean value	Standard deviation
Area under pineapple(ha)	0.709	0.063
Return from pineapple (Tk./ ha)	468404.93	36764.79
Land rent (Tk./ha)	82956.43	1548.19
Tillage cost (Tk./ha)	9492.53	599.32
Seedling cost (Tk./ha)	54684.01	12842.37
Manure cost (Tk./ha)	3235.37	643.52
Fertilizer cost (Tk./ha)	65911.08	3529.01
Hormone cost (Tk./ha)	8145.06	722.25
Labour cost (Tk./ha)	88329.75	4935.25
Total cost (Tk./ ha)	374904.15	24943.78

Source: Authors own calculation

**Table 2. Maximum likelihood estimates of the parameters of the Cobb-Douglas production frontier model for pineapple production**

Variable	Parameter	Coefficient	t-ratio
Intercept	$\beta_0$	4.011 (0.447)	8.969**
Ln (Area)	$\beta_1$	0.280 (0.095)	2.951**
Ln (Tillage cost)	$\beta_2$	0.025 (0.009)	2.772**
Ln (Seedling cost)	$\beta_3$	0.274 (0.090)	3.039**
Ln (Fertilizer cost)	$\beta_4$	0.047 (0.062)	0.758
Ln (Hormone cost)	$\beta_5$	-0.003 (0.007)	-0.429
Ln (Human labour cost)	$\beta_6$	0.339 (0.066)	5.152**
Dummy variable for variety (Giant kew=1, others=0)	$\varphi_1$	0.218 (0.125)	1.736
Dummy variable for cropping pattern (intercrop=1, monocrop=0)	$\varphi_2$	0.029 (0.096)	0.311
Variance parameters	$\sigma^2$	0.052 (0.013)	3.961**
Log likelihood function	$\gamma$	0.370 (0.182)	2.032*
		17.33	

Source: Authors own estimation. Figures in parentheses are the standard errors. \*\* and \* indicate significance at  $p < 0.01$  and  $p < 0.05$  respectively

Again, Table 2 exhibits that the sigma square (0.052) of the estimated model is statistically significant at 1% level of probability. This indicates a good fit of the distributional form assumed for the composite error term. The variance parameter gamma ( $\gamma$ ) which is statistically significant at 5% level of probability and associated with the variance of technical inefficiency effects in the stochastic frontier. The gamma parameter 0.37 implies that about 37% of the difference between the observed output and the maximum production frontier output is due to the differences in farmers' levels of technical efficiency as opposed to the conventional random variability.

The results of generalized likelihood-ratio tests of null hypotheses are presented in Table 3. The first null hypothesis relates to the functional specification, which is already mentioned above. Again, Table 3 indicates that the second null hypothesis of the non-existence of inefficiency effects is strongly rejected. The rejection of the null hypothesis supports the existence of inefficiencies in pineapple production. This implies that the traditional average response function is not sufficient for representing the production function. The third null hypothesis, which specifies that the inefficiency effects are not stochastic for this model, is also strongly rejected. The fourth null hypothesis specifies that the inefficiency effects of stochastic production frontier model is not a linear function of the age, education, member of cooperative society, credit, training and extension contact. This null hypothesis is also strongly rejected at 5% level of significance. This indicates that the joint effect of these six explanatory variables on the inefficiencies of production is significant although the individual effect of one or more variables may not be statistically significant. The inefficiency effects in the stochastic production is clearly stochastic and are not uncorrelated to the age, education, member of cooperative society, credit, training and extension contact. Thus, it appears that the proposed inefficiency stochastic production frontier model is significant improvement over the corresponding stochastic frontiers which do not involve model for the technical inefficiency effects.

### 3.3 Technical Efficiency Scores of Pineapple Production

Table 4 shows the percentage distribution of the pineapple farmers in the study area according to their technical efficiencies of production. The

percentage distribution of pineapple farmers' efficiencies indicates that the technical efficiency ranges from 0.61 to 1.00 with the mean technical efficiency of 0.9114. This implies that on the average, farmers are able to obtain 91.14% of potential yield from a given mix of production inputs. The indices of technical efficiency also indicate that if the average farmer of the sample could achieve the technical efficiency level of its most efficient counterpart, then average farmers could increase their output by 8.81% approximately [that is,  $\{1-(0.9114/0.9995)\} \times 100$ ]. Similarly, the most inefficient farmer suggests a gain of 38.36% approximately [that is,  $\{1-(0.6161/0.9995)\} \times 100$ ] if the farmer could increase the level of technical efficiency to his/her most efficient counterpart. The frequency distribution of technical efficiency indicates that 94% farmers' efficiencies lie between 0.71 and 1.00. These results coincide with the findings [33] for pineapple in Nigeria. The technical efficiency of pineapple production in the Edo State of Nigeria represents that 68% of the farmers' efficiencies lie between 0.71 and 0.8.

### 3.4 Determinants of Technical Inefficiency among Pineapple Farmers in the Study Area

This section intends to identify the significant factors that influence technical inefficiency of pineapple farmers at Madhupur upazila of Tangail district. The results of this section will be a basis for making agricultural policy on what needs to be done to improve productivity of pineapple farmers. Summary results in Table 5 show the determinants of technical inefficiencies. The coefficient for age is significant and the variable is positively related to technical inefficiency at 5% level of significance. The significant positive coefficient of age indicates that as the age increases farmers will become more inefficient. Perhaps, older farmers become more averse to risk and hesitate to adopt new technologies. As a result, technical inefficiencies are significantly lower for the younger farmers compared to old age group in the study area. This finding coincides with the results of [34]. The coefficient for education is significant and the variable is negatively related to technical inefficiency at 5% level of significance. The negative sign indicates that increase in human capital reduces the technical inefficiency of farmers. The sign is as expected because more the farmers are educated, more they will be efficient in production because of their better skills, access to information and good farm

**Table 3. Generalized likelihood ratio tests of null hypotheses for parameters of the inefficiency effect model for pineapple production**

Null hypothesis	Log-Likelihood under $H_0$	df <sup>a</sup>	Critical value ( $\chi_{0.05}^2$ )	Test statistic ( $\lambda$ ) <sup>b</sup>	Inference
$H_0: \beta_{jk} = 0$	17.32	21	32.67	27.94	Accepted $H_0$
$H_0: \gamma = \delta_0 = \delta_1 = \dots = \delta_6 = 0$	0.948	8	15.51	32.74	Rejected $H_0$
$H_0: \gamma = 0^c$	12.45	3	7.81	9.74	Rejected $H_0$
$H_0: \delta_1 = \delta_2 = \dots = \delta_6 = 0$	1.74	6	12.59	31.16	Rejected $H_0$

Source: Authors own estimation. <sup>a</sup> Degrees of freedom, <sup>b</sup>  $\lambda = -2[\ln \{L(H_0)\} - \ln \{L(H_1)\}]$ , <sup>c</sup>  $\gamma = 0$  indicates that  $\sigma_u^2 = 0$  and  $\delta_0 = 0$  so degrees of freedom corresponding to this hypothesis is 3

**Table 4. Percentage distribution of technical efficiencies of pineapple production**

Efficiency level	Technical efficiency (%)
0.61-0.70	6.0
0.71-0.80	6.0
0.81-0.90	24.0
0.91-1.00	64.0
Total	100.0
Mean	0.9114
Standard Deviation	0.0935
Minimum	0.6161
Maximum	0.9995

Source: Authors own estimation

**Table 5. Maximum likelihood estimates of the parameters of technical inefficiency effect model for pineapple**

Variable	Parameter	Coefficient	t-ratio
Intercept	$\delta_0$	-0.018(0.209)	-0.087
Age (years)	$\delta_1$	0.012(0.005)	2.235*
Education (years of schooling)	$\delta_2$	-0.025(0.011)	-2.275*
Member of cooperative society (yes=1, no=0)	$\delta_3$	0.203(0.122)	1.663
Credit (taken =1, not taken =0)	$\delta_4$	-0.016(0.104)	-0.150
Training (taken =1, not taken =0)	$\delta_5$	-0.169(0.223)	-0.761
Extension contact (yes=1, no=0)	$\delta_6$	-0.672(0.278)	-2.422*

Source: Authors own estimation. Figures in parentheses are the standard errors. \*\* and \* indicate significance at  $p < 0.01$  and  $p < 0.05$  respectively

planning. Literate farmers are better to manage their farm resources and agricultural activities and willing to adopt improved production technologies. Similar results were obtained in the works of [30].

Frequency of extension contact has exerted statistically significant negative relationship with technical inefficiency at 5% level of significance. This implies that a frequent contact facilitates the flow of new ideas between the extension agent and the farmer thereby giving a room for improvement in farm efficiency. Advisory service rendered to the farmers in general can help farmers to improve their average performance in the overall farming operation as the service widens the household's knowledge with regard to

the use of improved agricultural inputs and agricultural technologies. This result is also similar to those obtained by [31] and [33].

#### 4. CONCLUSION AND RECOMMENDATION

The main objective of this study is to estimate the level of technical efficiency and determine the factors influencing technical inefficiency of pineapple production using the Cobb-Douglas stochastic frontier approach. The study leads to the conclusion that technical inefficiency was present in pineapple production in the study area. The mean technical efficiency was estimated as 91.14% across the study area which means that farmers had been operating

their farms below the production frontier (100% efficient). So, the results indicate that there is still scope for 8.86% improvement in technical efficiency in pineapple production with the given technology without increasing the additional inputs. The results also indicate that area under pineapple cultivation, tillage cost, seedling cost and human labour cost were positively significant and more important in determining the technical efficiency of the pineapple farmers in the study area. The results show that age had significant positive influence on technical inefficiency. On the other hand, education and extension contact had significant negative influence on technical inefficiency. The significant positive coefficient of age indicate that technical efficiencies were significantly higher for the younger farmers in the study area compared to old age group. The significant negative coefficient of education implies that with greater year of schooling farmers tend to be less inefficient. The negative influence of extension contact implies that technical inefficiency will be reduced significantly by increasing the frequency of extension contact. With reference to the results, the study suggests that government should provide a favourable environment to encourage more youth to engage in pineapple production in a bid to increase productivity as well as alleviate poverty status and unemployment in the district and the country at all. This is because of attracting more youth in agricultural production is important since they are likely to be willing or able to properly allocate resources and adopt technical innovations. In addition, government has to give due attention to the education through strengthening and establishing both formal and informal types of farmers' education, farmers' training centers, technical and vocational schools, as education would reduce technical inefficiencies. Extension agents should improve the frequency of contacts with the farmers for bringing a positive effect of their services on the farmer's efficiency.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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