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RESEARCH ARTICLE

ANALYSES OF PRODUCTION VARIABILITY AND FACTORS AFFECTING TECHNICAL EFFICIENCY OF TOBACCO FARMERS IN TANZANIA

[1,*]Ernest N. Tingum, [2]Moses A. Ofeh and [3]Akwi Tafah-Oteh

[1]School of Public Policy (SPP), Central European University (CEU), Budapest, Hungary
[2]Department of Economics, Higher Teacher Training College, University of Bamenda, P.O Box 39, Bambili, Cameroon
[3]Department of Economics, University of Dar es Salaam, Tanzania

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ABSTRACT

In this paper, the factors affecting technical efficiency of tobacco farmers in Tanzania are examined. Tanzania is the third biggest producer of tobacco in Africa, after Zimbabwe and Malawi. About 0.08 percent of Tanzania's land (about 34,000 hectares) is allocated for growing tobacco. More so, Tanzania has great potential in tobacco production and it is one of the countries that is expected to dominate the African continent in terms of foreign exchange earnings. Using a stochastic frontier model (SFM) proposed by Battese and Coelli (1995), the paper estimates the levels of technical efficiency of 200 tobacco farmers using the maximum-likelihood method. The data used for the study were obtained from the Tobacco Control Policy Survey conducted in Tanzania in 2013. The survey was conducted in Sikonge, Uyui and Urambo districts in Tabora region. The districts were chosen to represent potential tobacco growing areas in the country. Results show that smallholder tobacco farmers in Tabora are significantly less efficient. Technical efficiencies of tobacco farmers range from 0.001 to 0.981 with a mean of 0.7162. In addition, farmers' characteristics such as age, primary level of education, keeping large family sizes, air breath during tobacco curling, extension agent's advice and distance to farm land are the major socioeconomic variables influencing farmers' efficiency.

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INTRODUCTION

Tobacco is an export crop grown worldwide in more than 120 countries (Rweyemamu *et al.,* 2006). In Tanzania, tobacco is one of the major agricultural export crops. Recently according to Kubajo (2012), tobacco was ranked as the number one foreign exchange earner in Tanzania. Tobacco sub-sector offers employment to many Tanzanians in both tobacco farms and in the tobacco processing factories. In addition, the crop provides raw material for cigarette manufacturing factories, thus offering further employment opportunities to people in the country (Rweyemamu *et al.,* 2006). The crop has considerable prospects to expand to the number one slot as the country has great potential to hold acreage or increase productivity or both. About 0.08 percent of Tanzania's land (about 34,000 hectares) is allocated for growing tobacco (Mackay *et al.,* 2006). Tanzania is the third biggest producer of tobacco in Africa, after Zimbabwe and Malawi (Jaffee, 2003). The country's tobacco output increased seven fold between 1975 and 1998 and continues to grow (Corrao *et al.,* 2000; Jacobs *et al.,* 2000). In Tabora region, flue cured tobacco production and its social profitability dates back several decades since colonial era. The crop creates much employment per hectare of cultivated land (Kuboja *et al.,* 2012). This fact depicts the potential of tobacco farming to farm families.Despite tobacco farming having a significant contribution to the economy of the country, the sector's performance in the region is low due to among others interlocking contracts, market distortions, poor credit arrangement and weak farmers cooperative societies (Rweyemamu *et al.,* 2006). In Tanzania there are currently a number of tobacco research activities taking place; which include preliminary flue and air cured tobacco varieties evaluation on yield and quality, evaluation of fertilizer in different rations on tobacco production in different soil status, evaluation of the effectiveness of farm yard manure in tobacco production versus inorganic fertilizers and evaluation of different chemical rates in controlling tobacco pests and suckers (Tobacco Research Institute, 2011). Despite all these research activities which have been carried out in different parts of the world few have been undertaken to study the extent of adoption and impact of the improved tobacco

***Corresponding autour:* Ernest N. Tingum,**
School of Public Policy (SPP), Central European University (CEU), Budapest, Hungary.

varieties. The Tobacco Research Institute of Tanzania (TORITA) and many tobacco companies which are operating in Tanzania and elsewhere, have been trying to supply improved tobacco varieties and fertilizers to improve output. Furthermore, small scale farmers in Tabora are still unable to produce a desirable level of output and preferred quality.

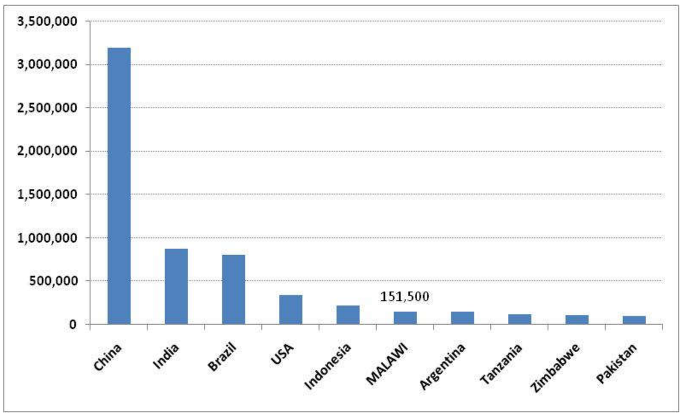


Figure 1. Top Ten Tobacco Producing Countries in the World in 2012, (MT)

Objectives of the study

The main objective of the study is to identify the policies likely to increase the productivity of tobacco producers in Tabora, through a better use of the factors engaged in tobacco production. More specifically, the study aims to:

- Estimate the level of technical efficiency of tobacco producers
- Identify and analyze the variables affecting their technical performance.

Significance of the study

This study is of both practical and theoretical importance. At the practical level, measuring technical efficiency of tobacco farmers, and identifying the factors that affect it, may provide useful information for the formulation of economic policies likely to improve farmers' technical efficiency. Moreover, from the microeconomic standpoint, identifying factors that may improve farm productivity is one of the major significance since, by using such information derived from such studies, farmers may become more efficient and hence more profitable. At the theoretical level, the study aims to bring some contribution to the understanding of farmer technical performance in developing countries especially in Tanzania. In fact, since the introduction of tobacco production in Tanzania, very few studies have been undertaken at the micro level to evaluate the technical efficiency level of farmers. The results of the study will fill this gap by adding to the few existing literature.

Benefits of Tobacco Production in Tanzania

Like in many other countries, tobacco production is important to the economy of Tanzania due to its contribution to the country's revenue. Tobacco production provides revenue to the government through excise taxes and export duties. As an export crop, tobacco earns a share of foreign exchange necessary to finance the imports of industrial goods, as well as to ensure interest payments on the national debts of Tanzania. At the microeconomic level, tobacco is also a very competitive crop. In effect, the net income per hectare for tobacco in Tabora is higher than that of other crops (maize, rice and groundnuts) cultivated by farmers in the region. In terms of rural development, the significance of tobacco specifically resides in the fact that it ensures the redistribution of income in rural areas. The crop constitutes an important source of income to the farmers and many other groups such as processors. At the environmental level, tobacco plants maintain the ecosystem and protect the soil against erosion, thus contributing to the preservation of the environment. At the producer level, it provides financial security to the farmers and represents a realizable asset that can be sold while still green before harvest to satisfy an urgent need for liquidity. Therefore, it serves as collateral for financial credit to farmers. It may also enhance land tenure security, since its presence on the land testifies to the farmer's ownership rights in case the land is not officially demarcated.

MATERIALS AND METHODS

Study area and Data

The study uses data from Tobacco Control Policy Survey conducted in Tabora in 2013. The survey was conducted in Sikonge, Uyui and Urambo districts in Tabora region. The districts were chosen to represent potential tobacco growing areas in the country. Tabora region was selected based on its agricultural potential. It is one of the regions in Tanzania, located in the central-western part of the country. With a population of about 2.2 million (National Census, 2012), the region is the 24th most densely populated with 30 people per square kilometer and a land area of 76,151 square kilometers representing 9 percent of the land area of Mainland Tanzania. The climate of the area is highly favorable for the agrarian activities of the population who grow crops such as tobacco, Maize, groundnuts, beans, and cassava. The annual rainfall is between 700 mm and 1000 mm, with the daily mean temperature around 23^{0}C (The Planning Commission of Tanzania, 1998). Data were collected with the use of a structural questionnaire designed for collecting information on output, inputs, prices of variables, and some important socio-economic variables about the farmers. Sample frame for this study consisted of all farmers growing tobacco in the study area. Primary data were collected using structured questionnaire which were administered to 360 respondents who are tobacco growers. Table 1 presents the summary statistics for some selected variables in the model.

Table 1. Summary statistics of selected variables

Variable	Observations	Mean	Percent
Quantity of Harvest (Kg)			
• *Tobacco*	200	1022.69	
Age (years)	134	58	
Household Size (Number)	200	6	
Farm Size (Acres)	200	9.6	
Off-farm income	195	360745.2	
Education level	200		100.0
• *No Education*	28		14.00
• *Primary Education*	150		74.95
• *Secondary and above*	22		11.05
Gender	200		100.0
• *Male*	148		73.82
• *Female*	52		26.18

Source: Survey data, 2013

From Table 1, the average age of a farmer involved in tobacco cultivation in Tabora region is about 58 years. In other words, farmers are mature and should be able to make rational decisions about the daily operations in the farms. The mean household size appears to be relatively high with 6 members per household. Mean acreage planted is 9.6 from which the mean harvest per acre is 1022.69 kg. Only 11.05 percent of the sample appears to have obtained secondary education and above while 26.18 percent are female headed household.

Measurement of variables

Quantity of Output: This is measured by the amount –in kg- of Tobacco output harvested.

Inputs: Inputs in the production function include, area planted in acres, manpower, fixed assets and expense on fertilizer.

Socio-economic Characteristics: These variables include Gender, Age (years), Level of Education, Household Size, Farm Size (acres). These variables will act as explanatory variables while estimating the equation on the determinants of efficiency.

Model Specification

Stochastic Frontier Production

While non-parametric methods do not take into account any noise, the stochastic frontier allows statistics to play a role which permits in constructing econometric models. The general stochastic model can be specified as:

$$y_i = f(x_i;\beta_i)\exp(v_i - u_i) \quad \text{..............................} (1)$$

Where y_i symbolizes the tobacco production of the i^{th} farm $(i = 1, 2, ..., N)$. It is clear that it can be described in terms of a physical quantity or in value term. The symbol f characterizes a functional form which can take on any mathematical form (i.e., Cobb-Douglas and translog). Here, x_i is the vector of all of the inputs included in the model. Inputs also can be described in terms of a physical quantity or in value terms. The model estimates β parameters. Stochasticity is introduced with the term $v_i - u_i$, a component of a composed error. The symbol v_i defines the random error and is distributed symmetrically. It includes all errors which occur due to model misspecification and other factors not under the farmer's control. The symbol u_i is the symmetric error term. It is independently and identically distributed. It captures the technical inefficiency of the farmer. It is worth noting that it is independent of v_i. The stochastic frontier model can be estimated by Maximum Likelihood (ML) or the Corrected OLS (COLS) method (Richmond, 1974). Coelli (1995) favored the ML estimator because of asymptotical appropriateness. Aigner *et al.* (1977) proposed the assumptions of a half-normal distribution and the log likelihood function. The most frequently-used output-oriented technical efficiency can be denoted as follows:

$$TE_i = \frac{q_i}{\exp(x'\beta + v)} = \frac{\exp(x_i'\beta + v_i - u_i)}{\exp(x_i'\beta + v_i)} = \exp(-u_i)$$

.... (2)

The TE score lies between zero and 1. When it is closer to 1, it is more efficient. As it gets closer to 0, it is more inefficient. When its score is equal to 1, the farm can be considered as being fully efficient (Battses and Coelli, 1995).

Inefficiency Effects Model

The objective of conducting a stochastic frontier model is not only to predict technical efficiency scores across farms, but also to investigate the determinants of efficiency differentials. A review of empirical literature shows that in earlier efficiency studies, different exogenous variables were included in the production function in line with the traditional inputs (See Battese (1992); Ahmad et al., (2002) for a detailed literature review on these studies). However, this approach immediately lost its popularity because of the vague explanation of inefficiency causes (Battese, 1992). Many studies have been conducted which have used either a variant of the corrected ordinary least squares (COLS) or the maximum likelihood method suggested by Richmond (1974). The maximum likelihood method is considered in this paper because of the availability of the software such as the Frontier 4.1 Program (Coelli, 1996) which has automated the maximum likelihood method. Therefore, inefficiency levels are defined to be exogenous factors' explicit functions, algebraically specified as;

$$\mu_i = \delta_0 + \delta_i Z_i \quad \text{....................................} (3)$$

The symbol μ_i denotes the mean technical inefficiency, Z_i is the set of exogenous variables assumed to influence the farmers' decision-making in tobacco production and δ_i is a vector of the parameters which has to be estimated. The ML approach is used in the estimation of β and δ, together with the variance parameter: $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$.

Empirical Specification

Battese and coelli (1995) proposed an empirical stochastic frontier production function, which has farm effects assumed to be distributed as a truncated normal random variable, in which the inefficiency effects are directly influenced by a number of variables. Given the objectives, the paper applies a Cobb-Douglas stochastic frontier expressed as follows:

$$In\,Y = \beta_0 + \beta_1 \, In\, X_1 + \beta_2 \, In\, X_3 + v_i - u_i \quad \text{............} (4)$$

Where:

InDenotes natural logarithms;

YTotal amount of harvest of each crop expressed in kilograms;

X_1 Labor input in man days*

X_2 Area of land cultivated in acres

X_3 Proportion of fixed assets used**

X_4 Amount used in fertilizer, pesticides and fungicides

v_i Independent and identically distributed random errors $N(0,\sigma_v^2)$. These are factors outside the control of the smallholders.

u_i Non-negative random errors or technical efficiency effects

The second stage of the analysis investigates farm-and farmer-specific attributes that have impact on smallholders' technical efficiency. The inefficiency function can be expressed as:

$$u_i = \alpha_0 + \alpha_1 z_1 + \alpha_2 z_2 + \alpha_3 z_3 + \alpha_4 z_4 + \alpha_5 z_5 + \alpha_6 z_6 + \alpha_7 z_7 + \alpha_8 \alpha_8 + \alpha_9 z_9 + w_i \quad \text{.............................. (5)}$$

Where:

$\alpha_{i's}$ Inefficiency parameters to be estimated

z_1 Gender of the farmer (1=male, 0 female)

z_2 Age of the farmer

z_3 Level of education (no education, primary education, secondary education or higher)

z_4 Household size (number of people staying together)

z_5 Farm size in acres

z_6 Air breath (feeling sick) of the person while currying tobacco (1=feeling sick, 0=otherwise)

z_7 Dummy variable assuming a value 1 if land is owned by farmer and 0 otherwise

z_8 Extension agent's advice

z_9 Distance between the farmer's house and the tobacco plot

w_i An error term that follows a half-normal distribution

In the model representing the production equation (4) and the inefficiency equation (5), the coefficients $\beta_0,\ldots,\beta_4$ and $z_1,\ldots,z_9$, and the variance parameters $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma_v^2$ are estimated by Maximum Likelihood (ML) method, using Frontier 4.1 software developed by Coelli (1996).In order to verify the hypothesis of this study and to choose between the Cobb-Douglas and the trans-log functional forms and the one that best represents the data, we carry out the generalized likelihood ratio test (LR). The ratio test statistics (λ) is calculated as follows:

$$\lambda = -2In\left[L(H_0 / L(H_1)\right] \quad \text{.............................. (6)}$$

Where $L(H_0)$ and $L(H_1)$ are, respectively, the values of the likelihood functions derived with and without constraints imposed by the null hypothesis (H_0), H_1 being the alternative hypothesis. If the null hypothesis is accepted, λ has a chi-square (or mixed chi-square) distribution with a number of degrees of freedom equal to the difference between the number of estimated parameters under H_0 and H_1.

EMPIRICAL RESULTS AND DISCUSSION

This section focuses on three issues. The first issue is the test of hypotheses of the study. The second issue is that, the parameters of the stochastic production frontier are estimated from which the efficiency levels are obtained and the third is based on the analysis of the determinants of technical inefficiency of tobacco farmers.

Test of hypotheses

Testing for the validity of the Cobb-Douglas specification using a log-likelihood test, we cannot reject the null hypothesis that the Cobb-Douglas frontier is an adequate representation. Given the Cobb-Douglas specification of the frontier function, the null hypothesis that there are no inefficiency effects $(\gamma = 0)$ in the model is tested. The hypothesis was rejected by the data for all the tobacco farmers. This result shows that average production function specification in which all farmers are assumed to be technically efficient is not an adequate representation.

Maximum Likelihood Estimates (MLE) of the Cobb-Douglas Stochastic Production Frontier for Tobacco Farmers

Table 3 shows the results of the Cobb-Douglas stochastic production function using Maximum Likelihood (ML) approach. The results from Table 3 show that the signs of all the estimated coefficients of the stochastic production frontier are positive which is consistent with a priori expectations. This implies that there is a positive relationship between the level of output of tobacco and labor, area of land cultivated, proportion of assets owned and amount used on fertilizer, pesticides and fungicides. This is expected as the level of tobacco production is a function of these inputs used in the farms. However, this can only be up to the level that is deemed optimal after which farmers will be operating at sub optimal level. Large areas of farm land if properly managed should have higher efficiency and output.

Table 2. Test of hypothesis for Cobb-Douglas function and technical efficiency

Null Hypothesis	Likelihood function	Calculated value	Critical value $(\chi^2_{0.05})$	Decision
1) Cobb-Douglas $(H_0 = \beta_i = 0 \; for\, all\, i = 1,\ldots,4)$	-96.84	16.05	17.67	Accept
2) No inefficiency effects $(\gamma = \delta_0 = \delta_1 = \ldots = \delta_{10} = 0)$		13.58*	10.37	Reject

Note: The critical value for the test involving $(\gamma = 0)$ is obtained from Kodde and Palm (1986).

Table 3. Maximum Likelihood Estimates of the stochastic production frontier for tobacco production in Tabora Region

Variable	Coefficients	Std errors
Labor	0.136***	0.044
Area of land	0.437***	0.028
fixed assets	0.027	0.007
Fertilizer and pesticides	0.864*	0.173
Constant	2.752***	0.101
Diagnostic Statistics		
Sigma square (σ^2)	23.5**	0.045
Gamma (γ)	34.2**	0.131
Likelihood ratio (λ)	82.24	
Log likelihood function	-96.84	

Source: Computed from Tabora field survey data, 2013
Note: ***, **, * show significance at 1%, 5% and 10% respectively.

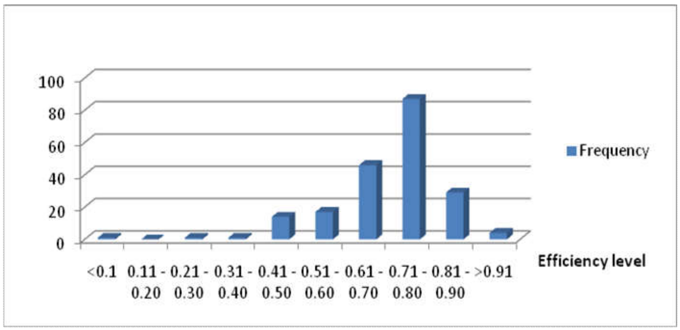
However, there is a threshold where return to scale decreases with increase in area of farm land cultivated. The results further show that the slope of labor and area of land were statistically significant at one percent level, which shows that labor and the area of land cultivated are important determinants of tobacco output. The coefficient amount used in the purchase of fertilizer, pesticides and fungicides is significant at ten percent and that of proportion of assets owned by the farmer is not significant. The diagnostic statistics of the stochastic frontier are explained by the coefficients sigma squared (σ^2) and gamma (γ). The value of sigma squared is 0.235 and statistically significant at five percent level. This value indicates a good fit and correctness of the distributional form assumed for the composite error term. As for gamma, it shows that the systematic influences that are unexplained by the frontier production function are the dominant sources of random error. From the table, the estimate of gamma is 0.342 and significant at five percent level. This shows the amount of variation resulting from the technical efficiencies of tobacco farmers in Tabora.

Hence, it implies that more than 34% of the variation in farmer's output is due to differences in technical efficiency. From Table 4 and Figure 2, the predicted farm specific technical efficiencies ranged between 0.001 and 0.981. A mean efficiency of tobacco farmers was 0.7142. Thus, in the short run, there is a scope of increasing output by 28.58 by adopting new technologies and techniques. 43.5% of the farmers had efficiency between 71% and 80%. This is probably due to the long years of tobacco farming experience in the area.

Table 4: Frequency distribution of technical efficiency estimates

Efficiency level	Frequency	Percentage
< 0.1	1	0.5
0.11 - 0.20	0	0
0.21 - 0.30	1	0.5
0.31 - 0.40	1	0.5
0.41 - 0.50	14	7
0.51 - 0.60	17	8.5
0.61 - 0.70	46	23
0.71 - 0.80	87	43.5
0.81 - 0.90	29	14.5
> 0.91	4	2
Total	200	100
Mean	0.7142	
Minimum	0.001	
Maximum	0.981	

Source: Derived from the output of Frontier 4.1 program (Coelli, 1996)



Source: Derived from the output of Frontier 4.1 program (Coelli, 1996)

Figure 2. Frequency distribution of technical efficiency indexes

Determinants of Technical Inefficiency of Tobacco Producers

Table 5 shows the analysis of the efficiency model. The signs of the estimated coefficients in the efficiency model have important implications on the technical efficiency of tobacco farmers. The coefficient of age of farmers is negative. This actually agrees with a priori expectation. As farmers grow old, there is a tendency that output will continue to fall owing to their declining strength to work in the tobacco farms. Farmers at their old ages are also exposed to many health hazards as a result of tobacco production. Hence, the older they are, the less efficient they become due to the fact that they are less likely to spend longer hours of the day in their farms. As a result of rural-urban migration, most of the tobacco farms in Tabora are left in the hands of the elderly and young children. The coefficient of family size is positive and highly significant at five percent level. This implies that increase in family size will lead to increase in technical efficiency. This conforms with a priori expectation given that tobacco production in Tabora utilizes more of family labor than hired labor. As a result, family heads prefer to have a large household working in the farms. The positive coefficient of gender indicates that the male farmers obtain higher level of technical efficiency than their female counterparts. Tobacco farming is dominated by males in Tabora. This is so because, firstly, most of the farm lands are owned by the men who would prefer to produce their own tobacco as it is the main source of revenue to many families in Tabora and the man is supposed to be the bread winner. Secondly, tobacco farming is a tedious job and requires strength which females may not be able to provide.

Table 5. Determinants of Technical Efficiency

Variable	Coefficient	Standard error
Gender	0.017	0.042
Age of farmers	-0.089**	0.022
No education	-0.308	0.172
Primary education	0.073***	0.008
Secondary and above	0.009	0.069
Household size	0.391***	0.004
Air breath	-0.021*	0.057
Ownership	0.195	0.186
Extension agent	0.050*	0.093
Distance to farm land	-0.045*	0.072
Constant	-2.734**	0.591

Note: ***, **, * is significance level at 1%, 5%, and 10% respectively

As concerns education, the a priori is that technical efficiency should increase with increase in level of education for farmers, since high level of education enhances the easy adaptability of new technologies and innovations. As Table 5 shows, farmers with no education reduce the technical efficiency level even though not significant. Farmers with secondary education and above contribute positively to the technical efficiency level. The coefficient of primary education level was positive and significant at the one percent level. This implies that technical efficiency increases with farmers who have acquired primary school certificates. This is plausible for Tabora given that a majority of farmers in the region have primary school certificate (see Table1).The negative coefficients of distance to farm land and air breath imply that efficiency decreases with farmers who travel long distances to their farms and the air breathe especially during the tobacco curling process. This process affects the health of farmers as they inhale the unprocessed tobacco. These variables are statistically significant at five percent level. The coefficient of ownership was positive but not significant. This implies that the level of technical efficiency increases with the ownership structure of farms but not significantly. The positive and significant coefficient of extension agent advice shows an increase in technical efficiency. This result agrees with a priori expectation since extension agent advice is likely to induce farmers in adopting different farming systems and innovations.

Conclusions and Policy Implications

The objective of this paper was to study the variability in productivity of tobacco farmers, by analyzing the factors that influence the technical efficiency of tobacco farmers in Tanzania. To achieve this objective, the Cobb-Douglas stochastic frontier function is estimated using the maximum likelihood method. This study reveals that tobacco farmers in Tabora are not fully technically efficient in their resource use.

The policy variables that were identified as having significant effects (positive or negative) on the efficiency levels of tobacco farmers are age, primary educational level, household size, air breath while curling tobacco, extension agent advice and distance to farm lands. Majority of farmers were almost ageing and this directly related to the reduction in the technical efficiency of tobacco farmers in the area. The 71.42% mean efficiency indicates that in the short run, there is a possibility of increasing production by about 28.58% by adopting the technologies and techniques practiced by farmers in the study area.

Limitations of the study

As in the case with most empirical studies, the model used may be limited because it might not be able to capture all factors. In the Case of this study, the application of the model does not consider factors such as risks, market imperfections, nutrition and medication that can also influence the technical efficiency of farmers. More so, the results obtained from this study should be considered as relative and not absolute in terms of applicability. Despite these limitations, we are confident that the results are the best that can be obtained given the circumstances. This is because the results have permitted us not only to estimate the technical efficiency indices of tobacco farmers in Tanzania but also to identify the factors that affect their technical performance.

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