Technical Efficiency Analysis of Tobacco Production in Tanzania

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Abstract

The measurement of efficiency in agricultural production determines the efficiency level of households in their farming activities. This will also determine whether small holder farmers make use of all the available potentials in their agricultural activities or not. This study measured technical efficiency (TE) of tobacco production and identified some determinants of technical inefficiency for the specified variables. Data were analysed using stochastic frontier analysis (SFA) method in the Cobb-Douglas production function. We deduced that the calculated technical efficiency was 64.7% meaning that there is still an opportunity to expand tobacco production using the current level of inputs and the technologies available in the area. There was also an indication for the improper use of two inputs; labour and CAN fertilizer. The variables of farm size, input credit use, off- farm income and education negatively influenced technical inefficiency. Only age of household head showed a positive relationship with inefficiency. Therefore this study propose that, since tobacco production is capital intensive and that most farmers are poor and would not manage to self finance their agricultural activities, then they should be encouraged to participate on the input credit system to enhance technical efficiency. Also, provision of better extension programs particularly on the proper use of farm inputs, raising education level of small holder farmers and farm management trainings will improve technical efficiency.

Key words: Technical efficiency, tobacco, Cobb- Douglas, frontier

1. Introduction

Tanzania government recognizes the contribution of agricultural sector to wealth creation of its people and to the GDP of the country. Through government's policy renovation efforts and through strengthening of institutional arrangements, the sector has experienced continual growth, with high and stable growth rates averaging 4.6 per cent per annum. The contribution of tobacco as one among the major cash crops in the country has been very significant. There is enough evidence that the crop, apart from significantly contributing to the national GDP, it has also contributed to the livelihood of the farming population. Recent statistics, for example shows that traditional exports in the country increased by 50.8% to USD 963.9 million in the year ending January, 2013 (BoT, 2013). This increase was largely due to a remarkable increase in the export volumes of the major four cash crops, tobacco being among them.

Due to intensive labour requirement, tobacco is commonly grown on small plots. Despite, there has been a consecutive increase in production and to-date, available evidence shows that the crop has been performing very well. The fact that Tanzania tobacco is competing with tobacco produced from other countries in the world, farmers are expected to operate under much more competitive conditions and increase their efficiencies in order to survive. Farm level efficiency is therefore becomes useful and important not only to individual tobacco farmers but more importantly to policy makers when deciding the magnitude of agricultural support coupled with the way the support and other resources should be allocated (Heshmati et al. 1995).

In estimating technical efficiency, a number of empirical studies suggest several alternative approaches to measuring technical efficiency (Battese and Coelli, 1995; Heshmati et al. 1995; Tadesse and Krishnamoorthy, 1997; Ruggiero, 1999; Liu, 2000; Iraizoz, 2003; Binam et al. 2004; Msuya and Ashimogo, 2005; Tijani, 2006; Alemdar and Oren, 2006; Obwana, 2006; Oren and Alemdar, 2006; Bozoglu and Ceyhan, 2007; Sadiq et al. 2009; Baten et al. 2009; Chen et al. 2009; Khai and Yabe, 2011), they are popularly grouped into parametric and non parametric frontiers. The main difference between the two is the assumption on the distributional form. Parametric frontiers impose a functional form on the production function and make assumption about the data. The functional form includes the Cobb-Douglas, constant elasticity of substitution and translog production functions. The non- parametric frontiers do not impose the functional form on the production frontiers and do not make assumption about the error term (Battese and Coelli, 1995; Alemdar and Oren, 2006). Furthermore, parametric models can be separated into deterministic and stochastic. The deterministic models assume that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise. According to Green (1993), the fundamental problem with deterministic frontier models is that any measurement error, and any other source of stochastic variation in the response variable, is embedded in the one- sided component making the resulting technical efficient estimates sensitive to outliers. Fortunately, the stochastic frontier model addresses this problem by incorporating a composed error structure with a two sided symmetric term and a one- sided component. The one sided component reflects inefficiency, while the two sided error captures the random effects outside the control of the production farm (Bravo-Ureta et al. 2007).

The non- parametric technical efficiency models are also referred to as data envelopment analysis (DEA). These are based on mathematical programming techniques. The main feature of DEA methods is that they do not require the specification of a functional form for the technology as it is the case for parametric models. The fact that these methods are deterministic, they suffer the effect of extreme observations. Another characteristic of DEA methods is the potential sensitivity of efficiency scores to the number of observations as well as to the dimensionality of the frontier (Ramanathan, 2003).

Common variables that have been used in estimating technical efficiency in previous studies are farm size, farming experience which sometimes exchanged with age of a household age, education level, credit use and use of extension services (Parikh et al. (1995); Seyoum et al. (1998); Liu (2000); Msuya and Ashimogo (2005); Chirwa (2007); Bozoglu and Ceyhan (2007); Chen et al.(2009); Eastwood et al. (2010); Khai and Yabe (2011)). The present paper introduce a new variable “input credit use” among explanatory variables in the model which was not used in the studies mentioned above.

In order to investigate technical efficiency level of tobacco production, we used the stochastic frontier approach due to its strengths in measuring technical efficiency in order to obtain reliable efficiency estimates.

The rest of the paper is organized as follows; in the next section, we provide the methodology. Section 3 gives details on the technical efficiency results and discussion of the results. We conclude in Section 4.

2. Methodology

2.1 The research area

This study was conducted in Urambo district, Tabora region where tobacco has been the most important traditional cash crop. The study area was chosen due to its potential in the crop production and its contribution to the Tanzania economy. Tobacco farming in the district is the major economic activity with more than 75% of all farmers being regular tobacco growers (Mangora, 2012). The district is the leading flue-cured tobacco producer in the country since independence (Waluye, 1994). Other main economic activities of the residents in the area are livestock keeping and honey gathering. Geographically, Urambo district lies between 31^0 24' and 32^0 47' Longitudes East, and 5^0 30' and 6^0 20' South. It covers an area of 25 995 km2; with a population of 369 329, of whom 340 348 live in rural areas. This proportion comprises about 92.2% of the total population (URT, 2003).The district is bordered by Uyui district to the East, Mpanda district in Katavi region in the South and Kaliua district of Katavi region to the Western side; whereas, Kahama district is in the North. Figure 1 provides the geographical location of the study area.

[Insert figure 1]

2.2 Stochastic Frontier Analysis

The stochastic production function was independently proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) and is used in the estimation of technical efficiency. The model has been extended however regarding both specification and estimation; see for example Greene (1993). A stochastic frontier model for an ith farm which produces Y output using X inputs is given by;

$$Y_i = X_i \ \beta + v_i - u_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(I)}$$

In the above equation (I), v_i is identically and independently normally distributed random error, $\left(i.e\ v_i \sim N\left[0, \sigma^2{}_v\right]\right)$ and captures random variation in output resulting from factors outside the farmer's control such as weather, natural disasters, diseases etc, measurement errors and left out explanatory variables. This component can either be negative or positive. On the other hand, the u_i reflects technical efficiency relative to the stochastic frontier of the ith farm and is defined as the difference between the farm's actual output and its potential output, using the same amount of inputs employed with the frontier technology. This is always positive $(u \geq 0)$ and according to Coelli and George (2005), it represents the technical inefficiency of the farm. The efficiency component u_i may assume half- normal, exponential or gamma distributions (Aigner et al. 1977; Meeusen and Broeck, 1977), but this study assumes a half normal distribution for u_i $\left(i.e\ u_i \sim N\left[0, \sigma^2{}_u\right]\right)$. We also assume that the two components, u_i and v_i to be independent.

For the same ith farm, the ratio of the observed output relative to the potential output estimated by equation (I) gives the technical efficiency of that particular farm. It follows that, technical efficiency denoted by $TE_i = \exp(-u_i) = \exp\left(-E(u_i/\varepsilon_i)\right)$............(II)

The value of TE ranges between 0 and 1, and represents the degree of technical efficiency. When TE equals 1 means the farm produces with fully technical efficiency, when TE < 1 means the farmer is not making the most, out of the inputs X_i with given technology embodied in the production function $f(X_i\ \beta)$ and since the output is assumed to be strictly positive $(Y_i > 0)$, the degree of technical efficiency is assumed to be positive. The maximum likelihood estimates of the parameters of function (I) and the farm level technical efficiency (TE) in equation (II) are achieved using STATA version 12.

2.3 Analytical Procedures for Measuring Technical Efficiency

Measurement of efficiency and estimation of production frontiers can be traced back in 1950s literature (see Koopmans, 1951; Debreu, 1951 and Farrell, 1957). Farrell (1957) provided definitions and a computational framework for technical and allocative efficiency. We learn from the literature on measuring technical efficiency that different methodologies have been proposed in measuring technical efficiency. The popularly known two approaches are well documented, the Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). Depending on the purpose of the researcher, the two approaches serves as alternatives, even if some studies may use both of them like in Sharma et al. (1999); Kwon and Lee (2004) and Alemdar and Oren (2006). Whether one uses either of the two methods or both, the selection of the methodology to use is arbitrary in the sense it is mainly based on the data available, objective of the study and sometimes personal preference of the researcher (Wadud and White, 2000). In the same line of argument, Rest (2000) concluded that there is no clear merit of one method over the other. DEA for example can easily handle multiple inputs and multiple outputs and allows direct comparisons of production possibilities without requiring additional input price data. Also it is a non-parametric programming model and therefore a prior specification of the production function is not required (Banker et al. 1984). In SFA, parameters of production functions are determined statistically and stochastic noise is taken care of in this approach. However, assuming a prior distributional forms for inefficiency component in SFA and imposing an explicit functional form for the underlying technology are the major weaknesses of this approach (Alemdar and Oren, 2006) yet in agricultural economics, the use of stochastic frontier methods is recommended due to its inherent nature of uncertainty associated with agricultural production such as bad weather, pests and diseases (see Coelli et al. 1998). More important however, stochastic frontier model are advocated over the deterministic models because of their ability to measure inefficiency (Ruggiero, 1999).

2.4 Empirical Model

There are several functional forms for estimating the physical relationship between inputs and output. However, if there are three or more explanatory variables in the model, the Cobb-Douglas functional form is still preferred (Hanley and Spash, 1993). In his paper on arguing a case for Cobb- Douglas production function, Murthy (2002) found that apart from its capability in handling multiple inputs in its generalized form, Cobb- Douglas does not even introduce distortions of its own in the face of imperfections in the market. The function is also capable in handling various econometric estimation problems such as serial correlation, heteroscedasticity and multicollinearity in an easy and adequate manner. It is further argued that Cobb- Douglas function facilitates computations and has the properties of explicit representability, uniformity and flexibility, further more, elasticities of individual inputs can be easily obtained, read and interpreted. A stochastic Cobb- Douglas production frontier was fitted to data as shown hereunder;

$$\ln Y = \ln \beta_0 + \beta_1 \ln land + \beta_2 \ln NPK + \beta_3 \ln CAN + \beta_4 \ln PESTICIDES + \beta_5 \ln labour + (v_i - u_i) \quad \ldots\ldots\ldots\ldots 1$$

where;

ln = Natural logarithm

Y = Tobacco output in kilogram (kg)

Land = Tobacco land area in acres

NPK = Fertilizer quantity in kgs (Nitrogen- Phosphorus- Potassium)

CAN = Fertilizer quantity in kgs (Calcium Ammonium Nitrate)

PESTICIDES = Pesticides quantity in litres

Labour = Man- day

v_i = random variable which is assumed to be identically and independently (iid) normally distributed with zero mean and variance $\sigma^2{}_v$

u_i = a non negative technical inefficiency and assumed to have half normal distribution

Since the production frontier represents maximum output whereas the cost function represents cost, we notice in our stochastic frontier that, for this reason Y_i is being subtracted instead of being added as a case of cost frontier. Parameters of the stochastic frontier model above can be estimated by using standard econometric methods. The stochastic production frontier is estimated using Maximum Likelihood (ML) estimates. We also fit the efficiency effect model of the following form;

$$u_i = \delta_o + \delta_1 TFASIZE + \delta_2 INCREDITUSE + \delta_3 EDU + \delta_4 AGEHH + \delta_5 OFFINC + \mu_i \ldots 2$$

Where;

TFASIZE = size of household's tobacco farm-land in acres

INCREDITUSE = dummy variable representing input credit use or not

EDU = represents education level of the farmer, (EDU1 dummy variable, 1 if a farmer has no formal education, 0 otherwise; EDU2 dummy variable, 1 if a farmer has primary education, 0 otherwise; EDU3 dummy variable, 1 if a farmer has secondary education, 0 otherwise and EDU4 dummy, 1 if a farmer has tertiary education, 0 otherwise)

AGEHH =representing age of a household head in years

OFFINC = farmer's income outside tobacco production (dummy, 1 = Yes, 0 otherwise)

The βs and δs in equations (1) and (2) are unknown and are to be estimated together with the variance parameters which are expressed as $\sigma^2 = \sigma^2{}_v + \sigma^2{}_u$ and $\gamma = \sigma^2{}_u / \sigma^2$ where the γ parameter has a value between 0 and 1.

There have been critics of the methodologies used to measure technical efficiency. Critics of the deterministic approach for example, argue that there is no allowance made for measurement error and other statistical noise which may bias the resulting measure of efficiency due to contamination of noise. Thus, this school of thought would argue that the stochastic frontier is as good as the deterministic approach (Ruggiero, 1999). Coelli (1995) and Ezeh (2004) concluded that the stochastic frontier approach is preferable for assessing efficiency in agriculture because of the inherent stochasticity involved. As a general conclusion of the methodology in measuring technical efficiency would be that, among the parametric approaches to measure technical efficiency, stochastic frontier models are better compared to deterministic models. Other studies that have used stochastic frontier methodology in measuring technical efficiency in agricultural production includes; Tadesse and Krishnamoorthy (1997), Liu (2000), Obwana(2006), Bozoglu and Ceyhan (2007), Chirwa (2007), Chen et al. (2009), Khai and Yabe (2011), among others. Therefore, the present study used stochastic frontier methodology due to its strengths in measuring technical efficiency in order to obtain reliable efficiency estimates.

3. Technical efficiency Results and Discussion

3.1 Descriptive statistics

Table 1 presents the descriptive statistics of some important variables applied in the stochastic frontier production model and some farm specific characteristics. The average tobacco land area of the farmers is around 2.5 acres with the minimum of half an acre (0.5) to a maximum of 12 acres. The standard deviation is 1.4, suggesting slightly big variability of tobacco farm sizes among the small holders. The average age of a farmer found to be 42 years with the minimum age of 22 years and a maximum of 86 years. This implies that the sample included both farmers with the age of a primary decision maker, the middle aged and the reduced strength farmers and all these may explain farm level inefficiency. Generally, the sample also included experienced tobacco producers with an average farming experience above 10 years, even though it was observed that the minimum farming experience was 1 year with a maximum of 54 years in growing the crop. The maximum total farm size owned by the farmers was 40 acres with a minimum of one-half acre.

[Insert Table 1]

3.2 Estimated Results

The maximum likelihood estimates of the parameters of the model are presented in Table 2. The estimated values for the variance parameters were significant and indicated that technical efficiency had an impact on the total value of tobacco production. This suggests that a conventional production function was not an adequate representation of the data. The variance parameter of the model (γ) was significantly different from zero at the 5 per cent level. Also, the presence or absence of technical inefficiency was tested in the study using the important parameter of log likelihood in the half-normal model $\lambda = \sigma_u / \sigma_v$, if $\lambda = 0$, then there were no effects of technical inefficiency, and all the deviations from the frontier were due to noise as in Agner et al. (1977). The estimated value of λ was 1.73 greater than 1 and significantly different from zero. The ratio of the standard errors was close to 1 $(\gamma = 0.75)$, indicating that a high level of inefficiency exists . In addition, the likelihood- ratio test was used to test the null hypothesis that there is no inefficiency effect and was strongly rejected at the 5 percent level, suggesting the existence of inefficiency effects for tobacco farmers in the study area.

The estimated elasticity for land, labour, fertilizer (NPK and CAN) and pesticides were 0.9743, -0.002, 0.4041, -0.0560 and 0.0832 respectively. Indicating that returns to scale were increasing with land, NPK and pesticides but decreasing with labour and CAN use. Only land have shown greatest elasticity, indicating that land has a major effect on the total value of tobacco production.

The results of efficiency analysis revealed that technical efficiency scores varied from 0.05 to 0.87 with the average technical efficiency level of 0.64 (64%). These results implies that there was substantial technical inefficiency in tobacco farming. The main implication of this result is that tobacco farms could reduce their inputs by around 36% without reducing their tobacco production, just by simply improving technical efficiency. Improved efficiency would reduce production costs and increase the gross margin on tobacco.

Regarding results of the inefficiency model, out of five variables used, age of a household head and input credit use had negative but significant coefficients. Most of the signs of the coefficients were as expected. Variables such as farm size, input credit use, off- farm income and education negatively influenced technical inefficiency and only age of household head showed a positive relationship with inefficiency (Table 2). The positive and significant age coefficient indicates that the younger farmers were more efficient than the older ones. This finding is consistent with and confirmed the results by Battese and Coelli (1995), Seyoum et al (1998), Liu (2000), Msuya and Ashimogo (2005) and Bozoglu and Ceyhan (2007). The age variable picks up the effect of physical strength as well as farming experience of the household head. Farmers definitely become more practised as they grow older, but the experience effect resulted from learning-by-doing is achieved more as they reach their middle age, as their physical strength begin to decline.

In our study we have also found that education negatively influenced technical inefficiency. This supports the hypothesis by Parikh et al (1995) and Asfaw and Admassie (2004) that education decrease inefficiency. We read from both old and recent literatures that education creates a favourable mental attitude for acceptance of new practices and farmers with at least basic education (like our sampled farmers), may respond more readily in using the new technology and produce closer to the frontier output, see for example Seyoum et al. (1998), Caswell et al.(2001) and Bozoglu and Ceyhan (2007).

Another finding of the inefficiency model is regarding the input credit use variable. We used this variable interestingly to capture the role of input credit use in influencing technical efficiency level in the tobacco production. This idea cropped up as we noticed during the interview some farmers who would like to be independent and to be excluded in the input credit use under contract farming configuration. We found the coefficient in the model to be negative and significant (Table 2). Tobacco production requires working capital from the farm preparation stage to the harvesting and grading before it is brought to the market for sale. Besides, production of this crop requires a high use of inorganic fertilizer mainly two; NPK and CAN plus pesticides. All these stages require sufficient working capital which lacks among small holder tobacco farmers in the area, but through contractual arrangement, they can be obtained on credit. Thus, the fact that purchase of agro inputs occurs during growing period whereas returns are received only after harvesting and sales several months later, it becomes a recurrent problem as almost all tobacco farmers have always negative cash flow during the start up of the production season to finance production. In this regard, input credit use becomes inevitable and thought to increase technical efficiency. Our finding confirmed results by Binam et al. (2004) and Bozoglu and Ceyhan (2007).

The insignificant negative relationship between farm size and technical inefficiency suggests that the larger the farm size the more the technical efficiency level, other factors being constant. In this case if a household has a good number of family members of working age and working capital, this result becomes possible. But since it is insignificance in our study then as far as efficiency determination is concerned, we are inconclusive.

Regarding the variable off- farm income, the estimated coefficient was negative and insignificant, showing a negative relationship with technical inefficiency. Relating to household size, this finding indicates that smaller households without off-farm income would have been more efficient than larger households with off-farm income.

[Insert table 2]

Frequency analysis of efficiency indices showed that 38 (12.7%) of the sampled farms had technical efficiency less than 50%, many farms revealed a technical efficiency level of between 60 – 80 percent (61.4%) and only 33 farmers (11%) had farms which were between 80 and 90 percent technical efficiency level as shown in Table 3.

[Insert Table 3]

4. Conclusion

This paper aimed at measuring technical efficiency and revealing factors for technical inefficiency among the surveyed sample of 300 tobacco farmers in Urambo district, Tanzania. However, it is our understanding that technical inefficiency can be reduced by a combination of efforts, perhaps training farmers on better means of agricultural production through extension services and advice; and an appropriate use of agro inputs combination. Specifically, we strengthen our conclusion on the following aspects;

Firstly; even though some tobacco farmers would not like to participate on input credit use under contract farming system due to its poor performance, we still see the role of input credit use as significant in increasing technical efficiency in the tobacco production. This is supported by the revealed fact that small holders do not have sufficient working capital to carter for the entire production process which requires high capital investment. It is our opinion that there is still a wide room and chance to refine the input credit system under the existing contract farming arrangement in the area. Such refinery may include among others, timely delivery of the inputs, delivery of the input amount as requested and timely payment of the balances after input loan deductions.

Secondly; our empirical results have revealed there was a misallocation or improper use of labour and CAN fertilizer inputs where the coefficient for natural logarithm of labour was negative and closer to zero while the coefficient for CAN use was also negative and insignificant (Table 2). More intervention should be on educating small holder farmers on the appropriate allocation of man days and CAN fertilizer use to have a well combination of the input use for increasing efficiency. Farmers should also adhere to standard use of fertilizer as specified by extension officers on one hand and buying companies on the other to have the required output.

Thirdly; we have revealed that the average technical efficiency in the sample was 64.7%, from a technical point of view; this value suggests that there is an opportunity to expand tobacco production using the current level of inputs and the technologies already available in the area. If small holder farmers may take advantage of the available extension services offered by both government extension officers in collaboration with buyers' leaf technicians, then they can improve both productivity and efficiency.

Lastly, although some of the variables included in the inefficiency model showed insignificant results, such as farm size, education and off- farm income, they have shown some interesting signs worthy noting. Thus the relationship between technical efficiency and farm size, education of farmer and off-farm income merits further research perhaps using a larger sample than we used or by incorporating other variables which were not used in the present study and in alternative tobacco producing area. As a result, future refinement of the model can be made and being implemented for the health and sustainability of tobacco crop in the country.

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Annexure

Item	**Mean**	**Std.Dev.**	**Min.**	**Max.**
Stochastic frontier variables				
Tobacco quantity (kg)	1363.49	1449.39	20	11181
Fertilizer				
NPK (kg)	373.08	163.24	100	1200
CAN (kg)	105.85	51.56	50	300
Pesticides (litres)	3.68	2.25	1	10
Tobacco land area (acres)	2.5	1.4	0.5	12
Labour (man-days)	*43.1*	*33.85*	*8*	*290*
Farm specific variables				
Age of head of household (years)	42.0	12.50	22	86
Total farm size (acres)	6.08	3.63	1.5	40
Farming experience (years)	15.0	11.46	1	54
Education of the farmer (years)	1.98	0.44	1	4

Table 1: Descriptive statistics of some important components in the tobacco production
Source: Own estimates, 2013

Variable	Parameters	Standard error	p-Value
Production function			
Constant	4.4086	0.53	0.000
ln (land)	0.9743	0.09	0.000*
ln (labour)	-0.0002	0.06	0.997
ln (NPK)	0.4041	0.12	0.000*
ln (CAN)	-0.0560	0.11	0.617
ln (Pesticides)	0.0832	0.05	0.097**
Sum of elasticity of inputs	1.41		

Variance parameters			
σ^2	0.87		
σ_v	0.466		
σ_u	0.808		
γ	0.75		
λ	1.73	0.11	
Log likelihood	-301.65969		
$\chi^2(1)$	18.43*		
Inefficiency effect			
Farm size (TFASIZE)	-0.0800	0.05	0.129
Input Credit use(INCREDITUSE)	-0.7213	0.34	0.033*
Education (edu1)	-0.9670	0.66	0.141
Age of household head(AGEHH)	0.0452	0.01	0.000*
Off-farm income (OFFINC)	-0.2116	0.34	0.537

Table 2: Maximum likelihood estimates of the Cobb- Douglas stochastic frontier model

*, ** significance at 5% and 10% level, respectively

Source: Own computations from survey data, 2012

TE interval (%)	Number (n)	Percentage
< 50	38	12.7
50- 60	43	14.4
60-70	97	32.4
70-80	88	29.4
80-90	33	11.0
Mean TE	64.7%	
Std . Deviation	14.96382	

Table 3: Distribution of technical efficiency scores

Source: Own computations from survey data, 2012

Figure 1: Location of the study area