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A comparative analysis of technical efficiency of smallholder tobacco and maize farmers in Tabora, Tanzania

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The study presented here considers the relative efficiency of planting tobacco and maize in the tobacco-producing Tabora region of Tanzania. The study used a 2013 survey that was conducted among smallholder farmers in the Tabora region. The aim was to investigate whether farmers are better off planting tobacco or maize. The paper briefly reviews the importance of agriculture in general and tobacco planting in particular on the Tanzanian economy. The paper then reviews the methodology used in the analysis, The Frontier Production Function. The findings show relative inefficiency in both tobacco and maize production. When the two are compared, one finds a statistically significant higher efficiency in the production of maize compared to tobacco. In other words, maize farmers can produce the same output utilizing 76.83% of the current input, while the corresponding value for tobacco is 73.89 percent. After generating the efficiency index of each farmer and for each crop, a multiple linear regression was estimated to identify significant determinants of efficiency. For the production of maize, five significant explanatory variables were identified (gender, age, education, household size, and farm size). For tobacco production, five explanatory variables including the variable “feeling sick while curing tobacco” were significant. In other words, the efficiency equation for maize has significantly better fit. In general, the efficiency indicators suggest that Tanzanian small scale farmers are more productive planting maize than tobacco.

Key words: Frontier, efficiency, tobacco, maize, Tanzania.

INTRODUCTION

The agricultural sector in Tanzania plays an important role in the overall economy through its significant contributions to rural employment, food security, and provision of industrial raw materials for other sectors in the country; thus, the performance of the overall Tanzanian economy is driven by the performance of the

agricultural sector (Ministry of Agriculture, Food Security and Cooperatives 2008). Agriculture in Tanzania employs the majority of the poor and has strong consumption linkages with other sectors. In 2011, the agricultural sector contributed approximately 51% of foreign exchange, 75% of total employment, and 27.1% of the

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Gross Domestic Product (GDP) (World Bank, 2013, 1996, 1994, 1991). Smallholder farming dominates agricultural production, and a large proportion of that farming is for subsistence. Since poverty is predominantly a rural phenomenon, and agriculture is a major economic activity for the rural population, it follows that success in poverty reduction depends critically on the performance of the agricultural sector. In terms of growth, the sector has achieved significant success in recent times, growing an average of 4.1% from 1998 to 2007.

Tobacco is one of the cash crops that helps generate foreign exchange earning in Tanzania. Tanzania ranks as a third African country after Malawi and Zimbabwe that is a major producer and exporter of tobacco. Tobacco is also consumed by Tanzanians with a prevalence rate of 10.8% (World Bank, 2013).

Before one considers a comparative efficiency of tobacco and maize production, it may be in order to highlight the health, social economic and environmental consequences of tobacco production. The negative health consequences of tobacco production such as the effect of curing, the high dependence on family and child labor and other hazards of being engaged in tobacco farming have been widely covered (Kagaruki, 2010; Mangora, 2005)

In the major tobacco-producing region of Tabora and other places in the country, government, extension agents, and companies are encouraging farmers to produce more tobacco by making credit available to purchase fertilizer and seeds. However, efficiency in the production of tobacco leaves a lot to be desired. Setting aside the negative health consequences of tobacco production and consumption, a benefit-cost analysis of tobacco farming may show that tobacco farming may not be a better option for small-scale farmers. Tobacco cultivation is labor intensive--farmers are in the field for 10 hours a day for 10 months a year from plowing the land to harvesting the crop. On the other hand, the gestation period for annuals such as maize or groundnuts is less than four months with relatively less labor input. In other words, it is possible with maize and groundnuts to have two or more harvests per year.

We hypothesize that farmers would be better off planting crops other than tobacco and that tobacco production is less efficient than the production of some other crops. This study compares production efficiency between tobacco and maize in the Tabora region of Tanzania. The aim is to investigate whether tobacco farmers would be better off growing maize, the main staple in the Tanzanian diet.

Objectives

The main objective of this study is to empirically determine and compare the efficiency of tobacco and maize farming in Tanzania. Specifically, the study seeks to:

1. Estimate frontier production functions for maize and tobacco and identify which is more efficient, and
2. Analyze the determinants of "Frontier" based efficiency for the two crops. .

Motivation

The motivation for this study is that both tobacco and maize production are important in the economy of Tanzania in general and in the Tabora region in particular. The market value for one kg of tobacco is three times that of maize. On the other hand, tobacco farming is more labor intensive and hazardous. It may not be sufficient to compare the gross revenue from tobacco with that of maize and conclude that farmers are better off cultivating tobacco. Setting aside the negative health consequence of tobacco production and consumption, one should also take into account the cost of production and compare the net revenue. Alternately, one may compare efficiency in the production of maize and tobacco. The main reason for choosing maize efficiency with tobacco is the fact that Tanzania is the largest producer of maize in Africa after Nigeria. In 2012 4.21 million hectare was planted with maize. This constitutes 70% of total acreage in the country (DTMA, 2014)

The study also is warranted because few studies exist on technical efficiency in the Tanzanian agricultural sector (Msuya and Ashimogo 2006; Msuya et al., 2008), and none in the area of tobacco production. Therefore, an empirical study to investigate technical efficiency in tobacco and maize cultivation in Tabora is a necessary first step in the national effort of improving resource use in the agricultural sector. Findings from the study will help to improve resource use efficiency in specific production areas, increase the contribution of agriculture to GDP, and enhance the earnings of small-scale farmers in the study area.

REVIEW OF ANALYTICAL FRAMEWORK

Methodological review

This study employs the stochastic frontier production function as proposed by Battese and Coelli (1992). The application of the function is in accordance with the early applications of Aigner et al. (1977) which originally developed the model to handle cross-sectional data. The tool has gained prominence in econometric and applied economic analysis in the last two decades. In Tanzania, few studies have applied this tool in the analysis of production functions especially in the agricultural sector.

This study applies the stochastic frontier approach for two main reasons: First, the method is capable of capturing measurement errors and other statistical noises influencing the shape and position of the production frontier (Battese, 1992; Msuya et al., 2008). Battese

extensively described techniques (deterministic versus stochastic, parametric versus nonparametric) that could be used to measure relative efficiency. Second, the technique better suits agricultural production largely influenced by random exogenous shocks like the one in Tanzania. This technique assumes that farmers may deviate from the frontier not only because of measurement errors, statistical noise, or any nonsystematic influence, but also because of technical efficiency.

Model specification

The methodology that is being adopted here is based the concept of frontier production function. The model decomposes the error terms into two, namely, the standard error term and an efficiency component. The latter measures the relative efficiency of each farmer in the study. This efficiency indicator gives a value between zero and one. Zero is given to the farmer who is completely inefficient and one if he is completely efficient. Once farmers are given this efficiency score, the model tries to identify the determinants of efficiency. These determinants are nothing but the characteristics of farmers such as age education, household size etc. A summarized theoretical specification of the model is given below Following Battese and Coelli (1992), the production function can be specified as follows:

$$Y_i = f(X_i, \beta) + e_i; \quad i = 1, 2, \dots, N \quad (1)$$

Where Y_i represents the previous potential output level (harvest) from the farms, X_i is a $(1 \times k)$ vector of inputs and other explanatory variables associated with the i^{th} farm. β is a $(k \times 1)$ vector of unknown parameters. The error term, e_i is composed of two independent elements, that is, $e_i = v_i - u_i$, with the v_i term being a random (stochastic) error associated with random factors not under the control of the farmers. It is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$, where σ_v^2 stands for the variance of stochastic disturbance v_i . u_i captures technical efficiency and is a nonnegative one-sided component associated with farm-specific factors. It is distributed independently from and identically to v_i . If farmers achieve their maximum output, then they would be technically efficient and this means that $u_i = 0$. u_i is associated with the technical inefficiency of the i^{th} farm and defined by the truncation (at zero) of the normal distribution $N(z_i \delta, \sigma_u^2)$, where z_i

is a $(1 \times m)$ vector of explanatory variables associated with technical inefficiency of production of farmers, and δ is an $(m \times 1)$ vector of unknown coefficients.

Following Battese and Coelli (1992), Shapiro and Muller (1977), the stochastic frontier production function can be specified in terms of the original values as follows:

$$\ln Y_i = f(X_i, \beta) \exp(v_i - u_i) \quad (2)$$

The model is such that the possible production Y_i is bounded above by stochastic quantity, $f(X_i, \beta) \exp(v_i - u_i)$, hence the term stochastic frontier.

The technical efficiency of an individual farm from the above specification can be defined in terms of the observed output to the corresponding frontier output, given the available technology (Amos, 2007). The technical efficiency (TE) is thus empirically measured by decomposing the deviation into a random component (u) (Ojo, 2003; Amos, 2007).

$$TE = \frac{Y_i}{Y_i^*} = \frac{f(X_i, \beta) \exp(v_i - u_i)}{f(X, \beta) \exp(v_i)} = \exp(-u_i) \quad (3)$$

Where Y_i is the observed output and Y_i^* is the frontier output, v_i is a standard error term while u_i is a measure of efficiency that follows a truncated normal distribution. This is such that $0 \leq TE \leq 1$. If farmers achieve their maximum output, then they would be technically efficient and this means that $u_i = 0$.

Study area

The data for this study were collected in Tabora, one of the major tobacco-producing regions in Tanzania. The units of observation are small-scale farmers. Even though tobacco is the major crop cultivated, farmers also are engaged in the production of other crops especially maize, a major staple in the diet of Tanzanians.

Tabora is a region in the central-western part of Tanzania. 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% of the land area of Mainland Tanzania. The climate of the area is highly favorable for the agrarian activities of the population, which grows crops including maize, groundnuts, beans, cassava, and tobacco. The annual rainfall is between 700 and 1000 mm, with the daily mean temperature around 23°C (The Planning Commission of

Table 1. Summary statistics of respondents' characteristics.

Variable	Observations	Mean	Percent
Quantity of harvest (Kg)			
Tobacco	259	1022.69	
Maize	252	1176.26	
Age (years)	134	58	
Household size (Number)	289	6	
Farm size (Acres)	306	9.6	
Education level			
No Education	45		14.71
Primary Education	226		74.83
Secondary and above	32		10.46
Gender			
Male	227		74.19
Female	79		25.81

Source: Survey data (2013).

Tanzania, 1998).

The data for this study were collected from randomly selected small-scale farmers in 2013. Data were collected with the use of a structural questionnaire designed for collecting information on output, inputs, prices of variables, and some important socioeconomic variables on the farmers. The sample size is 306 farmers; some respondents responded to only some of the questions thus causing a reduction in the number of observations for particular variables. Table 1 presents summary statistics of selected variables.

Table 1 shows the average age of a farmer involved in tobacco and maize cultivation in the Tabora region is 58 years. In other words, farmers are mature and should be able to make rational decisions about the daily operations of their farms. The mean household size appears to be relatively high; mean acreage planted is 9.6, while mean harvest per acre is 1022.96 for tobacco and 1176.26 kg for maize. Only 10.46% of the population appears to have a high level of education, while 25.81% are female-headed households, higher than the national average.

MEASUREMENT OF VARIABLES AND METHOD OF ANALYSIS

Quantity of output and inputs

These include the amount (in kg) of each crop (tobacco and maize), area cultivated in acres, family and hired labor, monetary value of fixed assets and fertilizer input.

Socioeconomic characteristics

These variables include gender, age (years), level of education, household size and farm size (acres). These variables will act as

explanatory variables while estimating the equation on the determinants of efficiency.

A two-stage frontier production function will be estimated. In other words, the following Cobb-Douglas frontier production function is estimated

$$\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + v_i - \mu_i \quad (4)$$

Where: \ln , denotes natural logarithms; Y is total amount of harvest of each crop expressed in kilograms; X_1 is labor input in man days; X_2 is area of land cultivated in acres; X_3 is proportion of fixed assets used; X_4 is cost of fertilizer, pesticides, and fungicides; v_i is independent and identically distributed random errors $N(0, \sigma_v^2)$. These are factors outside the control of the smallholders. μ_i is nonnegative random errors or technical efficiency effects

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

$$u_i = \alpha_0 + \alpha_1 z_1 + \alpha_2 z_2 + \alpha_3 z_3 + \alpha_4 z_4 + \alpha_5 z_5 + \alpha_6 z_6 + w_i \quad (5)$$

Where: $\alpha_{i,s}$ is inefficiency parameters to be estimated; z_1 is gender of the farmer (1=male, 0 female); z_2 is age of the farmer; z_3 is dummy variable for smallholder level of education (1= if the farmer has formal education and 0 if otherwise); z_4 is household size (number of people staying together); z_5 is farm size in acres; z_6 is air breath (feeling sick) of the person while curing tobacco; this variable used only in the tobacco equation (1 = feeling sick, 0 =

Table 2. OLS and MLE of the production function for tobacco and maize cultivation in Tabora region.

Variable	Tobacco		Maize	
	OLS	MLS (Half-normal)	OLS	MLS (Half-normal)
<i>Loglabor</i>	0.134(0.0768)*	0.0184(0.0438)*	0.0654(0.0960)	0.0385(0.0728)
<i>Logarea</i>	0.678(0.1580)***	0.932(0.126)***	0.648(0.1630)***	0.972(0.0870)***
<i>Logasset</i>	0.0542(0.0345)	0.171(0.0021)***	0.026(0.0467)	0.0111(0.0398)
<i>Logfertilizer</i>	0.00478(0.0123)	0.0280(0.0122)**	0.0673(0.0331)**	0.0350(0.0112)***
<i>Constant</i>	5.046(0.6820)***	4.894(0.0840)***	5.088(0.5700)***	6.364(0.3830)***
<i>R-sq</i>	0.431		0.277	
<i>F(4, 164)</i>	6.38***		9.01***	
$\ln \sigma_v^2$		-3.525(0.3014)		-5.112(1.0370)***
$\ln \sigma_u^2$		0.412(0.1090)***		0.224(0.1230)*
σ_v		0.0022(0.0030)		0.0776(0.4020)
σ_μ		0.8137(0.0443)		1.1186(0.0686)
$\sigma_s^2 = \sigma_v^2 + \sigma_\mu^2$		0.6622(0.0720)		1.2574(0.1508)
$\lambda = \sigma_\mu / \sigma_v$		0.0036(0.0443)		14.4144(0.9355)
<i>LR test of $\sigma_\mu = 0$</i>		87.82***		29.58***
<i>Observations</i>	169	169	190	190

*** p<0.01, ** p<0.05, * p<0.1. Values in parenthesis are standard errors for the ML estimation and robust standard errors for the OLS regression.

otherwise); z_7 is Dummy variable assuming a value of 1 if land is owned by farmer and 0 otherwise (rented); w_i is an error term that follows a half-normal or a truncated distribution.

The source of data, the sampling method as well as the sample size is already discussed previously. The specified models namely Cobb-Douglas production frontier defined in Equation (4) and the inefficiency model defined by Equation (5) are estimated using Ordinary Least Square (OLS) as well as the Maximum Likelihood (ML) method (Greene, 2007).

RESULTS AND DISCUSSION

The maximum likelihood estimation shows the presence of technical inefficiency effects in both tobacco and maize cultivation by smallholder farmers in Tabora region. In other words there is a significant level of inefficiency in both tobacco and maize production process. This result is confirmed by the statistical significance of the coefficients of $\ln \sigma_u^2$ as well as the log-likelihood ratio test of the overall maximum likelihood estimation. The highly significant value of $\ln \sigma_u^2$ suggests the domination of the inefficiency components of the error term for both tobacco and maize. With the exception of land area, all the other significant elasticities suggest values that are too small confirming the inefficiency in the production process.

In general, the results in Table 2 show a positive relationship and statistical significance between the levels of output (for tobacco and maize) and labor input, area of land cultivated, proportion of fixed assets used, and cost of fertilizer. This scenario is expected as the level of output depends to a certain extent on the quantities of these inputs used. However, this relationship can only exist up to a level that is considered optimal. After reaching this level, farmers will be operating at a suboptimal level (Amos, 2007).

Levels of technical efficiency

Once we estimate the frontier production function and establish the existence of technical inefficiency, the next step is to estimate the frequency distribution of technical efficiency (one minus inefficiency) indices. Table 3 presents the results.

Table 3 shows that the predicted technical efficiencies range between 0.000 and 0.9999 for tobacco farmers and between 0.003 and 0.91 for maize farmers. The mean efficiency for tobacco farmer is 73.9%, while that of maize farmer is 76.8% suggesting that tobacco farmers are less efficient than maize growers. The table also shows the t-test results for equal mean efficiencies with the null hypothesis of no significant difference in the mean technical efficiencies between tobacco and maize

Table 3. Frequency distribution of technical efficiency estimates and two sample t-test with equal mean efficiencies.

Efficiency level	Tobacco		Maize	
	Frequency	Percentage	Frequency	Percentage
<0.1	1	0.59	1	0.53
0.11-0.20	0	0.00	0	0.00
0.21- 0.30	0	0.00	1	0.53
0.31-0.40	1	0.59	5	2.63
0.41-0.50	2	1.18	9	4.74
0.51-0.60	3	1.78	10	5.26
0.61-0.70	25	14.79	25	13.16
0.71-0.80	62	36.69	61	32.11
0.81-0.90	45	26.63	31	16.32
>0.91	29	17.16	47	24.74
<i>Observ.</i>	169	100.00	190	100.00
Mean	0.7389		0.7683	
Min.	0.0000		0.0000	
Max.	0.9999		0.9926	
Two sample t-test with equal mean efficiencies				
Null hypothesis		H_0 :Difference in mean = 0		
t-value	-2.94***			

*** p<0.01, ** p<0.05, * p<0.1.

Table 4. Determinants of technical efficiency.

Variables	Tobacco	Maize
Gender	0.0152(0.0239)	0.0146(0.0363)***
Age	0.0009(0.0009)*	0.0011(0.0014)***
Noneduc	-0.0008(0.0659)	0.0149(0.1070)***
Primeduc	-0.0309(0.0649)*	0.0045(0.1000)***
Hhsize	0.0017(0.0049)**	-0.0026(0.0070)***
Farmsize	0.0009(0.0016)*	-0.0006(0.0019)***
Airbreath	-0.0249(0.0105)**	
Constant	0.7495(0.0985)***	0.515(0.1860)***

*** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses.

cultivation. The null hypothesis is rejected at a 1% level of significance showing that the mean technical efficiencies of tobacco are significantly lower compared with those of maize. In other words, tobacco farmers can produce the same output with only 73.9% of current inputs compared to a corresponding value for maize of 76.8%.

The determinants of efficiency

The efficiency effect model (Equation 5) tries to identify the socioeconomic determinants of efficiency among tobacco and maize farmers in the study area. The results are given in Table 4. According to the data in Table 4,

age, primary educational attainment, household size, farm size, and air breath (sickness caused by the process of curing tobacco) are the major determinants of efficiency of tobacco farmers; only age, household size, and primary educational attainment of farmers significantly caused inefficiency in maize cultivation. While variables such as no educational attainment and air breath reduced the efficiency level of tobacco farmers, other variables including primary educational attainment, household size, and farm size increased the efficiency level of tobacco farmers. On the other hand, farm size and no educational attainment reduced the efficiency of maize farmers in the model. Other variables increased the efficiency of maize farmers.

These results are plausible given that the majority of

farmers in the study are old and may not be willing to try or adopt new innovations or some may be less efficient in supervising their farms. Concerning household size, the major reason farmers have many household members is to provide farm labor. Thus the bigger the household size, the more labor is available for farming operations, hence increasing the efficiency of farmers.

Technical efficiency should increase with the farmers' level of education because being educated or being able to read or write increases the possibility of learning new farming techniques that will likely increase the efficiency of farmers. The negative coefficient of primary educational attainment indicates that farmer's education is an important variable in enhancing maize cultivation in Tabora. Previous studies obtained similar statistically significant results (Msuya and Ashimogo, 2006; Amos, 2007; Msuya et al., 2008).

The signs for the gender coefficient though not significant show that male farmers are efficient in tobacco and maize cultivation. Some studies have found similar results (Kibaara, 2005; Msuya et al., 2008). However, other studies have also reported no statistically significant results for the effect of gender on efficiency (Tchale and Sauer, 2007). Therefore, this study contributes to the ongoing debate on the role of gender in smallholder efficiency.

DISCUSSION

The issue of whether farmers are better off producing tobacco compared to other annuals and perennials has been addressed in many instances. When the earnings from tobacco are compared to the earnings from other crops such as maize, the former is much higher than the latter. This scenario is reversed when the corresponding input costs are considered. In other words, when net earning is estimated on per acre or per manpower, it appears that farmers in the study region are better off engaged in cultivating non-tobacco annual or perennial crops. Moreover, this finding does not take into consideration various health hazards associated with tobacco production.

In this study we tried to compare the production efficiency of tobacco and maize and were able to establish that producing tobacco is not a worthwhile undertaking compared to producing maize. Farmers in the Tabora region are relatively more efficient producing maize than producing tobacco.

When the determinants of efficiency were estimated for tobacco growers, the effect of tobacco curing reduces efficiency significantly. The findings from this study should enable policy makers to reconsider the prevailing notion that farmers are better off engaged in the production of tobacco and that the foreign exchange earning of the country is enhanced by producing tobacco. Many studies have already indicated that the negative health, social, economic and environmental consequences

of cigarette consumption and tobacco production as being significant. In this exercise we have tried to show that in spite of preferential treatment given to tobacco farmers in terms of fertilizer, better seeds, credit and market facilities. Tobacco growers appear to be less efficient. They ought to opt for alternative crops.

Conflict of Interest

The authors have not declared any conflict of interest.

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