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Analysis of technical efficiency and its determinants among tobacco producers in Uganda: An application of data envelopment analysis

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ABSTRACT

This study aimed at analyzing technical efficiency and its determinants among tobacco producers in Uganda. To achieve this, primary data were drawn from 200 tobacco farmers using semi-structured questionnaires. In order to determine the technical efficiency and its determinants, Data envelopment analysis and Tobit regression model were used for the analysis respectively. From the results, we observed that the mean TE was 49%, implying that the farmers were 51% inefficient. Furthermore, input prices, land size, farmers' age, farm income and farm location were found to be the determinants of technical efficiency. This study recommended that the government should subsidize farm inputs as well as training the farmers on input combinations in order to increase technical efficiency level.

Keywords: Technical efficiency, Tobacco, Data envelopment analysis, Tobit model, Uganda

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Introduction

Worldwide, tobacco (*Nicotiana tabacum*) is grown by 65% of the countries (ASH, 2009). In Uganda, tobacco is an annual crop mostly grown between the months of January to September. Generally, it does well in regions with high rainfall and soils with good water holding capacity. As such, the major tobacco producing districts include: Kiryandongo, Arua, Masindi, Kanungu, Koboko and Hoima districts. In these districts, there are three common varieties of tobacco grown by smallholder farmers. These include the flue-cured Virginia, dark-fire cured tobacco and the burley tobacco. The burley and dark- fire cured tobacco varieties perform well in areas with high rainfall and structured silt loam soils while the flue cured Virginia does well in regions with 800F during the day and 600F at night (Karemani and Nuwaha, 2019). Incidentally, Kiryandongo district has high rainfall and well-structured silt loamy soils and thus, a possible reason for widespread dependence on dark-fired cured tobacco variety (Karemani and Nuwaha, 2019).

Tobacco is one of the lucrative cash crops which has the potential to yield more revenues to the small holder farmers and improve their living standards (Keyser, 2002). However, its production yield is still low. This is evident from the unstable production pattern observed from the years 1995 to 2012 (WHO, 2015). Its yield per hectare increased from the years 1995 to 2005. However, from the year 2005 onwards, tobacco's yield has been fluctuating, attributed to farm resource misallocation leading to varied levels of inefficiencies. It is either the farmers are under-allocating or over-allocating their farm inputs. Allocating insufficient resources would lead to low production per unit area while over-allocation would result into input slacks, which is a waste. The commonality of the two scenarios is that they all result into some levels of technical inefficiencies.

In agriculture, technically efficiency refers to farm inputs combinations in order to achieve a desired quantity of output by the farmers (Okello *et al.*, 2019). According to Farrell (1957), farmers achieve 100% efficiency in production when they operate at the production frontier. However, previous studies have shown that operating at the production frontier alone is not enough measure for achieving full efficiency. As such, full efficiency in agricultural production is attained when farmers allocate their resources (input bundles) in such a way that they operate at the production frontier with zero input slacks. This implies that all the farm resources are utilized without wastages; a situation which is not common among smallholder farmers.

Past studies on technical efficiency in agriculture reported that farmers fail to attain full technical efficiency. For instance, Zamanian *et al.* (2013) applied data envelopment analysis and stochastic frontier analysis to determine technical efficiency among the MENA countries. They found out that farmers were 74.4% technically efficient. As a result, they concluded that farmers are inefficient in allocating their farm resources. This was not in odds with the findings by Tipi *et al.* (2009), who reported that farmers were 92% technically efficient and that the determinants of technical efficiency include farmers' age, group membership, non-farm income, land size and number of plots.

Abdulai *et al.* (2018) conducted a study on maize farming technical efficiency in Ghana using input-oriented data envelopment analysis. Their findings revealed that farmers were 77% technically efficient. In addition to this, they found out that majority of the maize farmers were exhibiting increasing returns to scale. In addition, their study found out that access to agricultural extension had a positive relationship with technical efficiency while level of education and agricultural mechanization had no significant relationship with technical efficiency.

Materials and Methods

Study area

This study was done in Kiryandongo district. This district is located 220 km away from Kampala towards the mid-western part of Uganda. It covers a total of 3,621 square kilometers with a total population of 266,197 persons, of which 50.3% are males (UBOS, 2018). It was purposively selected among other tobacco growing districts because it has high numbers of tobacco farmers. The favorable climatic conditions and high rainfall especially in August makes farming the major economic activity in this district (UBOS, 2018).

Data sources and sampling techniques

Structured questionnaires were used to collect data from 200 active tobacco farmers on a cross-sectional survey. The questionnaire was divided into three parts, the first part covered socio-demographic characteristics such as age, gender, farm size, access to credit, extension, group membership, household size among others; the second part covered resource allocation such as land allocated tobacco, seeds quantity, labour cost, fertilizers among others. Finally, the last part covered output variables such as quantity harvested, distance to the output market, transportation costs, and output prices among others.

Multistage and simple random sampling techniques were used. First, Kiryandongo and Kigumba sub-counties were purposively sampled based on the fact that these two sub-counties have the high numbers of tobacco farmers (UBOS, 2018). Secondly, in Kiryandongo sub-county; Kichwabugingo and Kyankende perishes were purposively selected while in Kigumba sub-county; Kigumba I and Kiigya sub-counties were also purposively selected. A list of all tobacco farmers was obtained from the district production officer to help access the farmers easily. To avoid, bias in the study participation, simple random sampling was then used to obtain a total sample of 200 farmers.

Data analysis

Data envelopment analysis

Data envelopment analysis (DEA) proposed by Salisu and Jiya (2016) was used to determine technical efficiency in the first step. Specifically, this study used input orientation under variable returns to scale DEA which is specified below (Tipi *et al*., 2009; Yilmaz and Yurdusev, 2011):

$$\begin{aligned} &\text{Min}_{\theta,\lambda} \quad \theta \\ &\text{Subject to} \quad -y_i + Y\lambda \geq 0 \\ &\qquad \theta x_i - X\lambda \geq 0 \\ &\qquad N1' = 1 \\ &\qquad \lambda = 0 \\ &\qquad \text{where}, i = 1, 2,2,3 \ldots \ldots i \end{aligned}$$

Where, $N1'$ represents a convexity constant, λ represents the $N \times 1$ vector of constant, X represents the input matrix, Y represents the output matrix, y_i represents a vector ($k \times 1$) output and xi represents a vector ($k \times 1$) input. The number of farmers is defined as i for this study. For every decision-making unit, there was N inputs (N= 4, i.e., land, fertilizers, labour cost and seeds) and M outputs (M= 1, Tobacco yield). The value θ represents the technical efficiency score ranging from 0 to 1. According to Farrell (1957), if the value of θ is 1, it implies full efficiency.

Tobit regression model

The goal of the second stage was to explain the determinants of technical efficiency. Having obtained technical efficiency scores ranging from 0 to 1 from the DEA in step one above, previous studies have found out that Tobit regression model has the ability to handle this kind of distribution (Tipi *et al*., 2010). As such, the second analysis of this study employed Tobit regression model to identify the determinants of technical efficiency. The efficiency scores obtained previously were then regressed as the dependent variable against the factors presumed to be affecting technical efficiency.

Tobin (1958) presented that Tobit regression model is specified as:

$$Y_i = \beta X_i + \mathcal{E}_i$$

$$Y_i = Y_i^* \text{ if } Y_i^* > 0$$
$$Y_i = 0, \text{if } Y^* \leq 0$$
$$Y^* = \beta_0 + \beta_1(X_1) + \mathcal{E}_1$$

Where,

Y_i^* is the dependent variable (technical efficiency), taking the numerical values ranging from 0 to 1, β_0 is the coefficient of intercept, β_1 represents the Regression coefficients, X_i are the regressors such as age, gender, farm size, farm income, farm location, use of hired labour, input prices, education level and distance to the nearest market while $\mathcal{E}_i$ represents the stochastic error term assumed to be normally distributed.

Socio-demographic characteristics of the farmers

Table 1 presents the socio-demographic characteristics of the farmers. The mean age was 41 years old with 16.26 years of engagement in tobacco production. The average household size was 8 household members implying that most of the farm labour came from the family. Farmers depended on an average of 4.08 acres of which 52% of the land was allocated to tobacco production while the rest were allocated to maize, cassava and sweet potatoes. This land allocation implies that in as much as farmers cultivate tobacco as a cash crop, they also acknowledge that they should produce food crops for household food security. On tobacco output, the farmers harvested an average of 4,121.50 kilograms of tobacco leaves making them to earn a gross income of 4,702,672.70 (1,333 USD) Ugandan shillings per season.

Results and Discussion

Table 1. Socio-demographic characteristics of the farmers.

Characteristic(s)	Mean	Standard deviation (SD)	Minimum	Maximum
Age (years)	41.05	13.45	18.00	87.00
Educational level (years)	6.28	4.68	0.00	28.00
Household size	7.50	3.40	1.00	20.00
Farm size (acres)	4.08	1.74	0.50	10.00
Farming experience (years)	16.26	10.82	1.00	48.00
Distance to the nearest market	3.05	1.80	0.00	12.00
Land allocated to Tobacco (Acres)	2.12	1.11	0.25	8.00
Tobacco yield (Kilograms)	1,141.01	1,106.43	100.00	7,000.00
Tobacco output price (Ugx)	4,121.50	1,276.50	1,000.00	7,200.00
Gender (Male)			152(0.76)	
Access to credit			148(0.74)	
Access to extension			172(0.86)	
Group membership			162(0.81)	

Description of the variables used in efficiency analysis

Table 2 presents the descriptive statistics for the variables used in efficiency analysis. The output used in this study was tobacco yield, which measured in kilograms. The average yield was 1,141 kilograms of tobacco. For the inputs, this study considered land, cost of hiring farm labour, seeds and fertilizers. Land was measured in acres, labour cost in Ugandan shillings while the unit of measurement for seeds and fertilizers was in kilograms.

Table 2. Descriptive statistics for the inputs and outputs.

Variables	Unit	Mean	Standard deviation	Minimum	Maximum
Output					
Tobacco yield	Kilograms	1,141.01	1,106.43	100.00	7,000.00
Inputs					
Land	Acres	2.12	1.11	0.25	8.00
Labour cost	Ugx	35,830.00	28,738.80	5,000.00	250,000.00
Seeds	Kilograms	4.50	2.45	1.00	20.00
Fertilizers	Kilograms	281.00	158.50	50.00	750.00

Technical efficiency

The results depicted in Table 3 confirmed that indeed tobacco farmers were technically inefficient. Specifically, the farmers were 49% technically efficient. This implies that up to 51% of the inputs were wasted. Strikingly, 69% of the farmers were producing below the 50% of the overall technical efficiency while only a quarter of the farmers attained the full technical efficiency. Based on the overall technical efficiency, farmers could reduce their inputs by 51% and would still attain the same quantity level. Many studies have confirmed some levels of technical inefficiency among small holder farmers. As such, the findings of this study is in agreement with the findings reported by Abdulai *et al.* (2018) who reported that maize farmers in Ghana were 77% technically efficient due to resource misallocation. Other studies which have reported varied levels of technical inefficiencies among smallholder farmers include; Bojnec *et al.* (2014); Madau (2012); Tipi *et al.* (2009). Zamanian *et al.* (2013).

Table 3. Distribution of technical efficiency scores.

Technical efficiency levels	Number of farmers	Percentage	Cumulative percentage
≤ 0.50	138	69.00	69.00
0.51 – 0.60	13	6.50	75.50
0.61 – 0.70	11	5.50	81.00
0.71 – 0.80	05	2.50	83.50
0.81 – 0.90	06	3.00	86.50
≥ 0.91	27	13.50	100.00
Mean TE			0.49

Technical efficiency determinants

The results showed that the model was adequate to present the determinants of technical efficiency. For instance, the model was significant at 1% level of significance, the pseudo-R square was 43.33% while the log likelihood ration value stood at -34.67 (Table 4).

Table 4 presents the results on the technical efficiency determinants. Based on the results, input prices had a negative but statistically significant ($P<0.01$) relationship with technical efficiency, an increase in input price by one unit would decrease technical efficiency by 19.66%. This was because the prices of seeds, fertilizers and pesticides were too high during the planting season than the harvesting season as this study was done during the planting season. The high cost of inputs was attributed by the high demand during the harvesting season. This conforms to the findings reported by Briner and Finger (2013).

There was a positive and statistically significant ($P<0.05$) association between farm income and technical efficiency. An increase in farm income by one unit would increase technical efficiency by 6.7%. This can be explained by the fact that when farm income increases farmers are more likely to get the capital for purchasing more inputs includes hiring enough labour, use of certified seeds and fertilizers for their farms making them more technically efficient. Additionally, more farm income would make the farmers to massively invest and enjoy the economies of scale which further increases technical efficiency. This is in line with the finding reported by Dogba *et al.* (2021).

The results further showed that land size had a negative and statistically significant ($P<0.01$) influence on technical efficiency. An increase in land size by one unit would result into a decrease in technical efficiency by 5.6%. This implies that small farms were more technically efficient than large farms. The negative association between land size and technical efficiency was attributed by farm labour use. Tobacco is a labor-intensive crop, from production to harvesting high labour is needed. However, farmers mainly depended on family labour. This was because majority of them could not hire labour for their farms due to financial constraints. In the long run, small farms would use the available family labour efficiently than those with large farms. Similar findings were also reported by Okello *et al.* (2019).

The positive and statistically significant ($p<0.10$) association between age and technical efficiency can be attributed to the fact that as farmers become older, they gain more years of farming experience. As a result, they are able to incorporate better cropping systems, better agricultural technologies, certified seeds and good agronomic practices, which increase technical efficiency. Additionally, older farmers are able to vary different farm input bundles in such a way that they attain the increasing returns to scale while maintaining production at stage two. This, in the long run, helps them to increase technical efficiency. This is in line with the findings by Weldegebriel (2014).

There was a positive and statistically significant (0.01) influence of farm location on technical efficiency. In this study, Kigumba and Kiryandongo sub-counties were considered for data collection. Farmers in Kiryandongo sub-county were more technically efficient than their counterparts in Kigumba. One of the major factors, which may have contributed to this, was the fact that Kiryandongo sub-county is the headquarters of Kiryandongo district. As such, it attracts more agricultural consultancies, trainings financial assistance to farmers, farm inputs, agricultural workshops that teach on inputs combination that maximizes farm yield making them technically efficient. This is in line with the findings by Okello *et al.* (2019), Adhikari *et al.* (2021) and Tsoho *et al.* (2012).

Table 4. Determinants of technical efficiency.

Variables	Coefficient	Standard errors	P>t
Input prices	-0.196	0.035	0.000***
Distance to the nearest market	0.029	0.039	0.449
Education level	0.004	0.003	0.234
Use of hired labour	-0.096	0.098	0.327
Farm income	0.067	0.027	0.014**
Land size	-0.056	0.018	0.003***
Age	0.109	0.062	0.079*
Farm location (Kiryandongo)	0.097	0.037	0.009***
Gender (Male)	0.047	0.043	0.274
Constant	1.996	0.597	0.001***
LR $chi^2(13)$		53.26	
Pseudo R2		0.4344	
Log likelihood		-34.67	
Prob>Chi^2		0.0000	
N		200	

, ** and * represents statistical significance at 10%, 5% and 1%, respectively.*

Conclusion and Recommendation

This study concluded that tobacco farming technical efficiency is as low as 49%. Implying that 51% of the farm resources were wasted, a situation, which calls for more interventions to increase its level. On the determinants of technical efficiency, this study concluded that land size and input price have a negative influence on technical efficiency while farm income, age of the farmers and farm location has a positive influence on tobacco production technical efficiency. It is based on these results that this study therefore recommends that 1) The Ministry of Agriculture, Animal Industry and Fisheries should subsidize farm inputs in order to increase technical efficiency so that the less privileged farmers can access them cheaply, 2) We recommend farm resource allocation trainings by extension workers so that farmers can know how to mix different inputs to improve technical efficiency.

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