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Leveraging the Stochastic Frontier Model for Optimal Technical Efficiency in Tanzanian Maize and Paddy Crops Production

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ABSTRACT

This study evaluates the technical efficiency of maize and paddy production among smallholder farmers in Tanzania, focusing on identifying socio-demographic and institutional factors that influence inefficiency. Agriculture is critical to Tanzania's economy, contributing significantly to GDP and rural livelihoods. However, low productivity and inefficiency persist, particularly in maize and paddy farming. This study aims to assess the levels of technical efficiency and determine the socio-economic and institutional determinants that affect production efficiency in these crops.

This study utilised data from the 2014/15 National Panel Survey, comprising a sample of 1,699 household heads from a targeted population of 3,352 households. A stratified two-stage sampling design was employed, with data analysed using Stochastic Frontier Analysis (SFA). The Cobb-Douglas production function was used to estimate technical efficiency, while socio-demographic factors such as age, education, marital status, household size, and institutional variables such as credit access and training were incorporated into the inefficiency model.

The findings reveal that the average technical efficiency for maize and paddy production is 51.45% and 33.27%, respectively, indicating significant potential for output increases without additional resources. Maize farmers exhibited higher efficiency levels than paddy farmers. The key determinants of inefficiency include age, education, household size, and access to extension services and training. Younger, educated, and married farmers and those with access to training and extension services demonstrated higher efficiency levels.

The study recommends promoting access to modern agricultural inputs, such as improved seeds, fertilizers, and mechanisation to enhance productivity. Strengthening extension services and farmer-led organizations is crucial for improving knowledge dissemination and resource access. Additionally, tailored training programs and adult literacy initiatives should be implemented to equip farmers with relevant skills and improve efficiency. Addressing these inefficiencies is essential for boosting agricultural productivity, ensuring food security, and improving rural livelihoods in Tanzania.

Keywords: Technical efficiency, Maize production, Paddy production, Stochastic frontier analysis, Cobb-Douglas production function, Tanzania agriculture

INTRODUCTION

In Tanzania, the agriculture sector has undergone regular change throughout technological innovation adaptation (Food and Agriculture Organization [FAO], 2016). The adoption of agricultural innovations has changed the traditional farming practices of many smallholder farmers and brought about noteworthy success in food crop production (Dirk *et al*. 2015). The great achievements in agricultural improvement and food crop production have played a part in poverty alleviation. For example, from 2006 to 2012, the minimum resources needed for physical wellbeing (basic poverty) declined from 34.4% to 28.2% (World Bank [WB], 2015). This constant decline in poverty is strongly linked to improvements in agriculture, which employs about 65 percent of the country's population mostly located in rural areas (Bank of Tanzania [BOT], 2018). Furthermore, agriculture during the period from 2015 to 2016 contributed about 29.0 percent to 29.1 percent of the total Gross Domestic Product (GDP) (BOT, 2017). Food crops, such as paddy and maize, play important roles in food insecurity to meet the consumption needs of household members. Its cultivation is significant in meeting the food needs of poor rural households, particularly in developing countries, such as Tanzania. Household food security is attained if food is available at relatively low prices (Odebode and Ogunsusi, 2006).

The estimation of food efficiency in agricultural production plays a significant role in agricultural development and provides helpful information in the decision-making process in the wise usage of factors of production and policy formation related to improvement in agriculture sectors. Nevertheless, efficiency plays an important role in reducing food insecurity within the community (Dessale, 2019). Kalibwani (2018) proposed that knowing the level of technical efficiency has been important in the advancement of agricultural production which is associated with an increase in the wealth of smallholder farmers and poverty alleviation. Moreover, Dhehibi *et al.* (2014) put forward that enhancement in the technical efficiency of food production is the first rational step towards significantly increasing crop production in the least developed countries. Thus, smallholders' attainment of knowledge on relative factors of production to output ratio is crucial to help farms have a better chance of surviving and policy makers draw up appropriate policy measures (Dhehibi *et al.* 2014).

Regardless of the importance of the technical efficiency of food crops associated with increasing productivity in sub-Saharan Africa (SSA). However, low food production remains a challenge for smallholder farmers in developing nations (FAO, 2017). For instance, Tefaye and Beshir (2014) agreed that significantly introduced interventions purposively to increase the level of outputs have been prone to inefficiency. The presence of production inefficiency is due to insufficient utilisation of available modern technology in food crop cultivation (Tefaye and Beshir 2014). FAO, (2013) point out the challenges faces the sub-Saharan Africa namely: low purchasing power of most small holder famers, high cost in mechanization, insufficient of agriculture credit, lack of well-trained machinery operators, importation of tools and machinery of poor quality (FAO, 2013).

In Tanzania, the Ministry of Agriculture, Livestock, and Fisheries presented the main challenges facing agriculture in production at full potential. The first is the low accessibility of factors of production such as land, labour, and capital (United Republic of Tanzania, 2015a). This is attributed to insufficient financing to acquire production inputs such as labour-saving technologies, improved quality seeds, fertilisers, chemicals, and pesticides. Second, there is over dependence on rain due to underdeveloped irrigation (URT, 2015a). Third, deprived rural infrastructure such as rural roads, railways, market linkage, inadequate communication facilities, well water supply, storage, processing facilities, and electrification are largely underdeveloped (URT, 2015a). The fourth challenge is the low quality of agricultural products which is associated with low market prices. Another challenge is too little involvement of the private sector in agri-business, due to the inherent risks associated with agriculture. A last-mentioned challenge is associated with environmental degradation and disease (URT, 2015a).

Paddy plays a significant role in China's agricultural production sector for the stability of food security for the majority of the community. In 2018, the first leading nation in paddy production was China with approximation of 1484490MT, followed by India with 116000MT. In East African counties, Tanzania is the leading producer of paddy with 2046MT, followed by Uganda and Kenya with 179MT and 79MT, respectively (FAOSTAT, 2019). In Pakistan, paddy is the first and most remarkable cash and food crop that contributes to elevating the nation's gross domestic product (GDP) which contributes more than 2 million tons to food supplies and a significant basis of employment opportunity creation to improve livelihoods for rural communities. Its significance in the national economy and share of rice in agriculture is approximately 3.1 percent and 0.7 percent of GDP, respectively (Government of Pakistan, 2014).

Maize is the most important source of energy for approximately 962 million individuals throughout sub-Saharan Africa and is consequently significant in increasing food security. Maize dominates the cereal industry for almost 40 percent of the total cereal demand, followed by rice which accounts for 27% (FAO, 2015). The greater production of maize in Africa is attributed to the expansion of the land area coupled with supporter input programs that increase the convenience of modern inputs to boost small-scale farmers in cultivation/production. The five largest maize producers in Africa are Nigeria, Tanzania, Madagascar, Guinea, and Mali which all contribute nearly 65 percent of the development in cultivation. Despite remarkable expansion in production, demand continues to rise in cereal imports and exceeds 49 Mt by 2025; for example, there are more than 20 percent of wheat and rice imports in Sudan and Nigeria (OECD / FAO, 2016). Moreover, within these products, all nations in the region remain in deficit, and net exports increase throughout the region over the next century,

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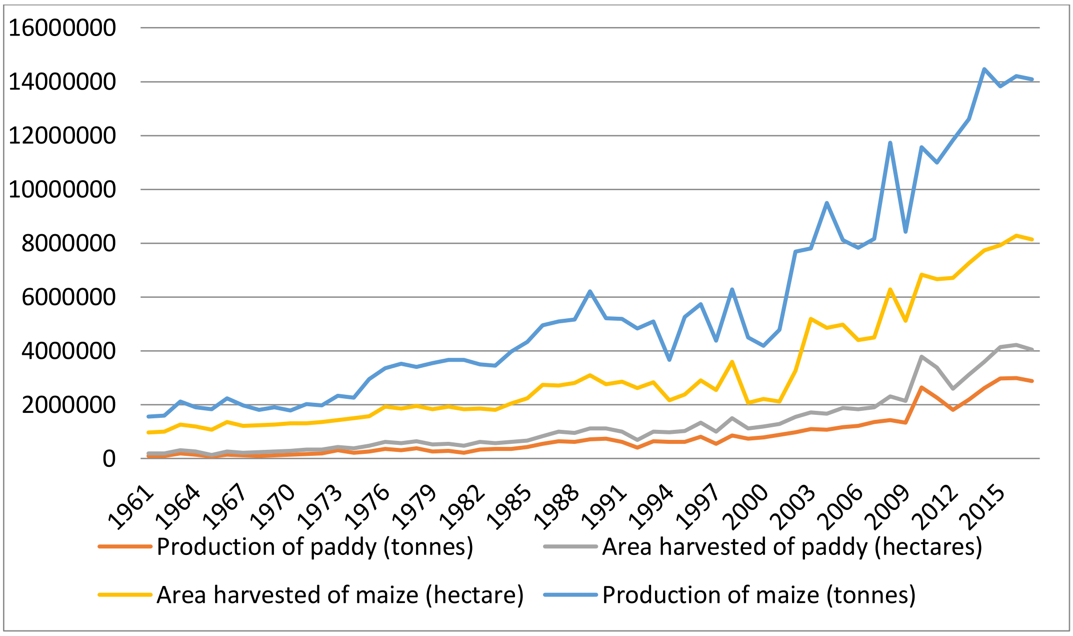
with few exceptions for rice. The Sub-Saharan Africa (SSA) region has excess grain, which is expected to decline by 2025, and the trade balance remains positive for both maize and other coarse grains (OECD/FAO, 2016). Traditional excess producers like South Africa, Zambia, and Ethiopia continue to export the biggest share, while Kenya and Zimbabwe remain the biggest shortage economies (OECD / FAO, 2016).

In Tanzania, maize and paddy are significant food crops, with approximately 5,356,000 tons and 2,194 and 750 tons, respectively, cultivated during 2012/2013, contributing greatly to the Tanzanian community in food security and livelihood, mostly in rural areas. From the production of both maize and the paddy season of 2005/06 up to 2012/13, the production increased and started to decrease from 2015 to 2017 (see Figure 1.2). In general, the trend for paddy production (tones) has normally increased from 1,238,560 tons in 2005/06 to 2,194,750 tons in 2012/13 agriculture year (see figure 1.2) (FAOSTAT, 2018). The presence of little fluctuation with years is due to changes in climate conditions, such as rainfall intensity, where rice-growing areas depend on the rainy season (FAOSTAT, 2018). Regionally, Morogoro has the uppermost paddy cultivation yield in Tanzania, followed by Mbeya, Tabora, and Njombe. Moreover, Kusini Pemba was the foremost in the Zanzibar cultivated area, followed by Kaskazini Pemba, while Mjini Magharibi had the lowest area cultivated. The total harvested land with paddy fields in Tanzania was approximately 991,909 ha, of which 97.8% was harvested in the Mainland and 2.2 percent in Zanzibar (URT, 2018).

Figure 1.2: Production of Paddy and Maize in Tanzania (1961-2017)



Source: FAOSTAT, (2016)

In Tanzania, maize is the main basket, but the participants in crop cultivation are still mainly small-scale and medium-sized farmers using a traditional technique in cultivation and characterised by a small amount of output. About 5,766,984 tons were produced in Tanzania, of which 99.9% was produced in the Tanzania Mainland and 0.1 percent produced in Zanzibar. In mainland Tanzania, Mbeya represents the uppermost maize producer, followed by Tanga, Tabora, and Morogoro, whereas Dar es Salaam reported the lowest maize producer (URT, 2018). Figure 1.2 indicate that high production of maize in Tanzania occurred during 2008 and 2014, accounting for 5440710 tons and 6737197 tons, respectively, and production fell to 5939737 tons in 2017 (FAOSTAT, 2018).

In Tanzania, the policies of maize and paddy in the agriculture subsector formulated in different periods of time have primary objectives to increase production to ensure households' self-reliance and food security (URT, 2016). In Tanzania, there are various strategies/polices for enhancing the development of agriculture sectors; for instance, the National Development Vision which highlights that by 2025 Tanzania's economy will have been misshapen from a low-production agricultural economy to a semi-industrialised one (Boulay, Morrissey, and Leyaro, 2014; URT, 2016). The second is Kilimo Kwanza which developed due to the global food price crisis during 2008/2009 and gave rise to renewed attention in the agriculture sector. The success of Kilimo Kwanza was the result of the active involvement of the private sector, and nearly all plans were intended to improve technology adoption (e.g. improved seeds, mechanisation, and fertiliser), expand market linkages, and encourage exports (URT, 2016).

Moreover, from the most recent decade, a number of polices/strategies have been created to hold up agriculture in a more efficient way. For example, the Agricultural Sector Development Strategy (ASDS) was adopted in 2001 and gave rise to the Cooperative Development Policy (CDP) of 2002 and the Agricultural Sector Development Program (ASDP) of 2005 (Boulay and Morrissey and Leyaro, 2014). In addition, the strategy and ASDP are embedded in the National Strategy for Growth and Reduction of Poverty (NSGRP), which is a medium-term plan to realise Vision 2025. Kilimo Kwanza, developed in 2009, provides additional inputs for the implementation of ASDP and other programs favourable for the agricultural sector (Boulay and Morrissey and Leyaro, 2014). These policies created purposively in advancement in accessibility of efficiency of production input, increased access to credit, advancement in extension services availability, and increased investment in rural areas (especially for irrigation and transport). Finally, the Rice Council of Tanzania (RCT) was formulated in 2015 to assist the best engaging, supportive, coordinating, and well-prearranged trading system for rice stakeholders in improving performance, sustainability, and profitability (RCT, 2015).

Despite these agricultural strategies and policies, which are associated with short- and medium-term developments in agriculture, technical efficiency has been insufficient due to the inability to match food demand among communities. Nevertheless, advancement in agriculture remains an important policy objective in least developed countries, where agricultural productivity is still low (FAO, 2016) as a result of inefficient cultivation. For instance, critical food shortages were reported in some areas in the regions of Lindi, Mtwara, Singida, Dodoma, Simiyu, Mara, Shinyanga, and Arusha (BOT, 2017). During the year ending June 2016, the National Food Reserve Agency (NFRA) distributed 313,612.4 tonnes of food as follows: 32, 965.8 tonnes as subsidised food through Prime Ministers' Office to vulnerable people; 4,263.4 tonnes to prisons department; 23,999.8 tonnes to World Food Program (WFP); and 252,368 tonnes to millers/traders to increase supply and stabilise prices in the market. Table 1.1 present the food production in 2014/15 and requirement in 2015/16 (BOT, 2017). Thus, substantial effort must be devoted to estimating productive efficiency, which has been the subject of a myriad of theoretical and empirical studies for several decades since Farrell's (1957) seminal work.

Table 1.1: Food Production in 2014/15 and requirement in 2015/16

Zone	Production	Requirement	Surplus/Deficit	Self-sufficient ratio
Centre	2,174,737	1,944,045	230,692	111.9
Dar es Salaam	57,630	1,297,114	-1,239,484	4.4
Eastern	2,308,697	1,567,598	741,099	147.3
Lake	4,872,266	4,038,881	833,385	120.6
Northern	2,100,054	1,965,865	134,189	106.8
Southern	4,015,436	2,132,620	1,882,816	188.3
Total	15,528,820	12,946,123	2,282,697	119.9

(Source; BOT, 2017)

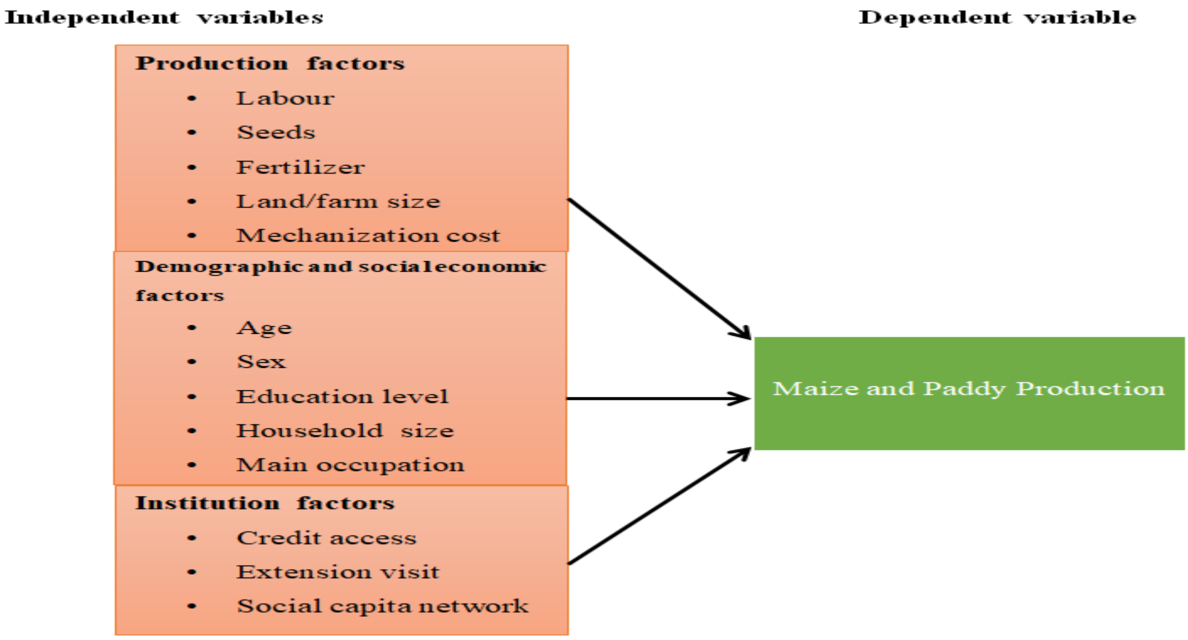
Different authors have been put forward concerning the technical efficiency of maize and paddy food crop production. Most studies have pointed out that the coefficients of variables such as organic fertiliser, chemical fertiliser, labour, and machinery usage are positive and significant factors for increasing paddy efficiency levels by 80.42 per cent in the Indian environment (Rajendran *et al*. 2018). In China, the average technical efficiency of indica-type rice is 0.90 which is higher than the 0.88 technical efficiency of japonica rice (Xibao Luan, 2007).

In western African countries, such as Nigeria, the average efficiency scores of swamp rice and upland rice are 56 percent and 91%, respectively (Bamiro and Janet 2012). Gunda (2013) points out that efficiency level of smallholder maize farmers in Zimbabwe lies on average of 77 %, and in Kenya lies on average of 53% (Kwena, 2016). 67% was maize technical efficiency observed in Ghana (Bempomaa & Cquah, 2014), and finally Musaba and Bwacha (2014) reported in Zambia farm level technical efficiency ranged between 52.2% and 93.2%, with a mean of 79.6%. On the other hand, different authors put forward different factors associated with inefficiency of maize and paddy production, such as education, membership in self-help groups, loan accessibility age, sex of smallholders, family size, fertiliser usage and farming experience, access to credit, and extension visits (Msuya and Ashimogo (2007); Rahman *et al*. (2012), and Zhuo *et al*. (2013), Mkanthama *et al.* (2017); Kidane *et al*. (2015); Achandi (2018)). Thus, the current study adds a more comprehensive approach by using household data for the entire country to estimate the technical efficiency of food crop production in mainland Tanzania, which is different from other studies, which are mostly based on the primary data for a specific geographical area within a particular country.

Objective of the study

To assess the technical efficiency of maize and paddy production among smallholder farmers in mainland Tanzania and identify socio-demographic factors that influence technical efficiency.

Figure 2.1: A conceptual framework



Source: Author Construction (2025)

STUDY METHODOLOGY

The study was conducted in mainland Tanzania using secondary data from the national panel survey wave 4. This study focused on measuring the technical efficiency of maize and paddy production among smallholder farmers in regions of Tanzania mainland that cultivate these crops extensively. This study only measured technical efficiency and did not consider economic or allocative efficiency. The study involved only the heads of households cultivating maize and paddy producers in mainland Tanzania. The sample design for this study was a stratified two-stage design. The design consisted of 51 design strata (identified in the data as 'strataid') corresponding to a rural/urban designation for each of the 26 regions in Tanzania mainland. However, Dar es Salaam, a purely urban area, constituted only one stratum. The allocation across the design strata was informed by the last round of the National Panel Survey (NPS) and aimed to balance multiple survey objectives and maximise precision given the survey parameters. The intended sample design consisted of a new selection of 3,360 households corresponding to 420 Enumeration Areas (EAs) from the latest Population and Housing Census (PHC) in 2012. This new NPS 2020/2021 cohort will be maintained and tracked in all future rounds between national censuses. This research adopted secondary data obtained from the National Panel Survey Data 2020/2021 of Tanzania, which was generated by the National Bureau of Statistics (NBS). These data are used for academic purposes only to assess the technical efficiency of maize and paddy production among smallholder farmers in mainland Tanzania and to identify socio-demographic factors that influence technical efficiency. The targeted population consisted of 3352 households and a sample of 1699 head of households studied from the National Panel Survey of 2014/15, as shown in Table 2.1. This study applied Stochastic Frontier Analysis to estimate the level of TE.

Table 2.1: Number of Clusters and Households in Samples of NPS 2014/15 by Area

Location	Cluster	Number of households
Tanzania	419	3,352
Tanzania mainland	359	2,872
Dar es salaam	69	552
Other urban mainland	68	544
Rural	222	1,776
Tanzania-Zanzibar	60	480

Source: NBS (2017)

After obtaining clearance and approval, the research was conducted following ethical guidelines, utilizing 2014-2015 National Panel Survey data from the National Bureau of Statistics. Confidentiality and welfare of information were ensured, and plagiarism was checked before submission, no household member identification was published. The variables used in the current study were divided into two parts (i.e. dependent and independent variables). The dependent variables were maize and paddy output, measured in kilograms (kg). Furthermore, the independent variables employed were divided into those incorporated in the efficiency model which measures the efficiency score, and those incorporated in the inefficiency model. The variables included to measure the efficiency score are farm size, labour, fertiliser, seed, and mechanisation cost, sometimes they are named as factors of production used in the Cobb Douglas production function which are all continuous. Moreover, the variable included in inefficiency was divided into three groups as study-specific objectives, namely, demographics and social economic factors.

ANALYSIS METHODS

Econometric model

First, the stochastic frontier function (parametric) is one of the two most significant methods for estimating the efficiency level. The i^{th} company's technical efficiency is estimated by the proportion of the measured yield to the highest possible yield as indicated in equation 1-3 as follows,

$$TE = \frac{Y_i}{Y_i^*} \quad \ldots\ldots (1)$$

$$TE = \frac{\exp(X_i B)\exp(V-U)}{\exp(X_i B)\exp(\mathrm{V})} \quad \ldots\ldots (2)$$

$$TE = \exp(-U) \quad \ldots\ldots (3)$$

Second, the non-parametric approach has the capacity to accommodate various outputs and inputs in the assessment of technical efficiency. Nevertheless, the potential effect of random shock, such as measurement mistakes and other noise in the information, is not taken into account (Coelli, 1995). However, the stochastic frontier does not support various inputs and outputs. It is also more likely to be affected by misrepresentation problems. Additionally, it incorporates stochastic elements into a model; however, it improves its applicability in the assessment of the technical efficiency of agricultural production.

Stochastic frontier production

A number of earlier studies specified a Cobb-Douglas production function to represent the frontier function; however, the Cobb-Douglas inflicts a severe restriction on the farm's technology by restricting the production elasticities to be constant (Wilson *et al*., 1998). This study employed the flexible trans-log model to specify stochastic border cultivation/production features. The model is defined as follows:

$$lnY_i = \beta_0 + \sum_{k=1}^{n} \beta_k \, lnx_{ki} + \frac{1}{2} \sum_{k=1}^{n} \sum_{j=1}^{n} \beta_{kj} \, lnx_{ki} lnx_{ji} + \varepsilon_i \text{ ………………….. (4)}$$

But we know

$\varepsilon_i = v_i - u_i$

Where, *ij* represent to the jth observation of the ith farm

Y_i Refers to the total value of rice and maize output

β_0 and β_k are parameters to be estimated

x_{ki} and x_{ji} are explanatory variables

On the other hand, the inefficiency model is estimated from equation (5) specified below:

$$u_i = \alpha_0 + \sum_{m=1}^{n} \alpha_m \, z_i \text{ ……………………………………………………….. (5)}$$

The variables z_i represent the inefficiency variables such as demographic features of head of household, area of land cultivated, and agricultural extension visit and availability of financial assistance. Equation (6) shows the combined estimation of a stochastic frontier function (Green, 2002).

The explicit Cobb-Douglas stochastic frontier is specified below:

$$lnY_i = ln\beta_0 + \sum_{i=1}^{12} \beta_i lnX_i + V_i - U_i \text{ ………………………………………. (6)}$$

V_i Are assumed to be independently and identically distributed random errors, fall under normal $N(0, \sigma_v^2)$ distribution and the U_i are non-negative one-sided random variables, known as technical inefficiency effects which is associated with the small-scale farmers. It is assumed that the inefficiency effects are independently distributed with a half normal distribution $(U \,|N(0, \sigma_u^2)|)$. Equation of technical inefficiency influence the stochastic frontier of equation (12) is defined by

$$U_i = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \cdots \dots \dots .. + \alpha_5 X_{16} + W_i \text{ …………………..... (7)}$$

Where by,

Dependent variables

Y_1 Production output paddy

Y_2 Production output maize

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Variable in production equation

X_1 Farm size (hectare)

X_2 Labour (man-days)

X_3 Quantity of Seed used (kg)

X_4 Quantity of fertilizer used (kg)

X_5 Mechanization cost

Variables in inefficiency equation

X_6 Sex

X_7Age

X_8 Marital status

X_9 Household size

X_{10} Education level

X_{11}Occupation

X_{12} Social capital network

X_{13} Land ownership

X_{14} Training

X_{15} Extension visit

X_{16} Access to credit

$W_i$are unobservable random variables, which are assumed to be independently distributed with a positive half normal distribution and α_i *and* $\beta_i$coefficients are unknown parameters to be estimated, together with the variance parameters which are expressed in terms of

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (8)$$

$$\gamma = \frac{\sigma_v^2}{\sigma_u^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots\ldots (9)$$

Where γ the parameters range from 0 to 1, the parameters of the stochastic frontier function model estimated by method of maximum likelihood. The model for inefficiency effects can only be estimated when the inefficiency effects are stochastic and have a particular distributional specification.

Hence, there is interest to test the null hypothesis that the inefficiency effects are not present, $H_0{:}\, \gamma = \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$.

This null hypothesis was evaluated using the test and t-test of the generalised probability ratio. The generalized probability-ratio test is a one-sided test as the negative values cannot be taken byγ. Under both the null and alternative hypotheses, the generalised probability ratio test requires model assessment. The model is equal to the traditional average answer function U_i under the null hypothesis $H_0{:}\, \gamma = 0$

This study is based on several hypotheses. Maybe the most evident is due to the nature of the data. The information is evaluated on the largest and lowest fields in which rice and maize were planted by a family during the primary rainy season harvest in 2020/2021.

The second hypothesis is that production has the same function as production. In addition, the research assumes that the specification of the stochastic frontier model includes all productivity inputs and socioeconomic features.

Lastly, the premise that the compound error term ($e_i = u + v$) is symmetrically distributed separately as $N(0, \sigma^2 v)$ random variables independent of u. Furthermore, it is presumed that u is a non-negative half-normal truncated distribution, $N(0, \sigma^2 v)$. The output of rice and maize weighing less than one bag was regarded as an outlier and was therefore excluded from the research.

In this study, production economic theory was employed to examine the technical efficiency of food crop cultivation. This production association can be articulated in more than a few forms: Leontief (fixed coefficients), linear functional, Cobb-Douglas (double log), Constant Elasticity of Substitution (CES), and Variable Elasticity of Substitution (VES) production functions. The Leontief function assumes zero elasticity of substitution between factors of production, the linear function assumes factors to be perfect substitutes, and the Cobb-Douglas function has a unitary elasticity of factor substitution. The functions of CES and VES do not assume any specific value for substitution elasticity, but as their names imply, the former takes this elasticity as a constant, while the latter allows it to vary. Thus, the elasticity of factor replacement determines the shape of the manufacturing function. Factor substitution elasticity is a measure of simplicity with which it is possible to substitute the varying factor for others. In practice, production variables are replacements, but this connection is far from ideal.

RESULTS AND DISCUSSION

Estimation of level of technical efficiency

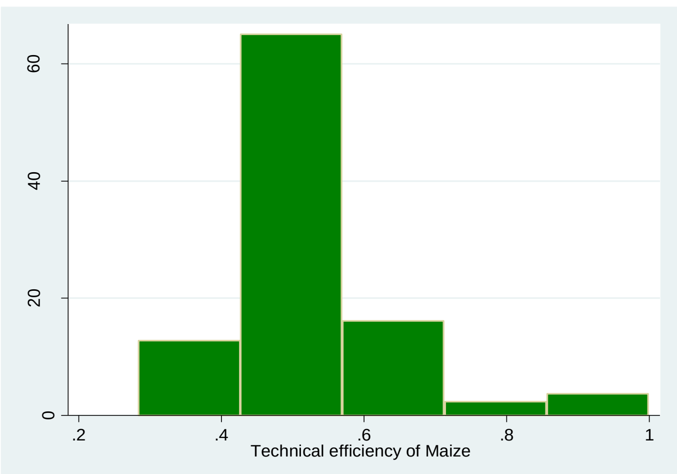
In Table 4.4, the technical scores for maize and paddy cultivation are presented, revealing that, on average, the households surveyed achieved technical efficiency levels of 51.45% for maize and 33.27% for paddy. A comparison of technical scores indicates that maize smallholders exhibit higher technical efficiency than paddy smallholders do. The distribution in Figures 4.0 and 4.1 further illustrates this difference, with a majority of small-scale maize farmers falling within the 0.4 to 0.6 technical score range (more than 63%), while most individual paddy farmers scored between 0.2 and 0.4 (comprising 48%). These findings suggest a significant discrepancy in technical efficiency between individual maize and small-scale paddy farmers.

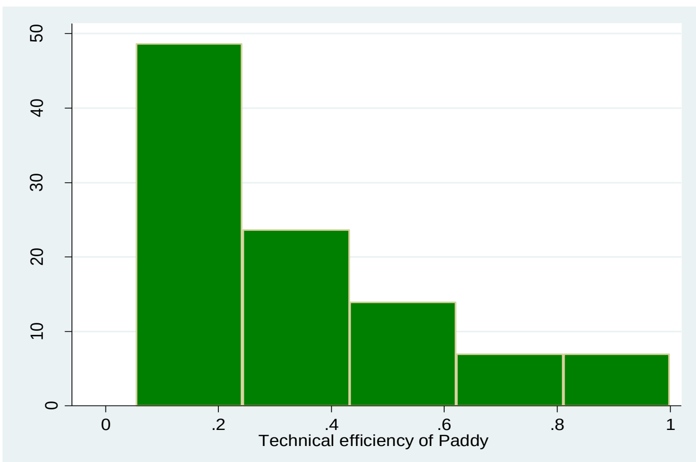
Table 4.1: Technical efficiency level

Efficiency	Mean	Std.dev	Min	Max
Maize	0.5144579	0.1312569	0.2830404	0.999318
Paddy	0.3326627	0.249375	0.0536744	0.999994

Source: Author's computation based on NPS data (2014/15)

Figure 4.2-3: Graph of technical efficiency of Maize and Paddy





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Determinants of Technical Efficient of Maize and Paddy Production

The results in Table 4.2, education exhibited a significantly negative influence on inefficiency in small-scale maize farmers, indicating that educated farmers were more efficient. However, for paddy, education had a positive but insignificant influence on efficiency, with a more substantial impact on technical inefficiency in paddy fields than in maize. Extension visits positively affected technical efficiency in maize but had no influence on paddy. Farmers' age had a significant positive impact on inefficiency in paddy production, suggesting that older farmers were less efficient. Marital status had a negative and significant impact on paddy inefficiency, implying that married farmers were more efficient. Household size had a positive and significant effect on inefficiency in both crops, indicating that larger households were less efficient. Belonging to a social capital network reduced inefficiency in maize but had no effect on paddy. Paddy as the main occupation and training attendance had negative and significant impacts on inefficiency in their respective crops, suggesting that specialisation and training improve efficiency. Overall, the standardised coefficient for paddy was higher in several cases, emphasising the importance of factors in paddy cultivation compared to maize.

Table 4.2: Parameter Estimates of the Stochastic Frontier Model

	Stochastic frontier for maize				Stochastic frontier for paddy			
Frontier	Coef.	Standardized Coef.	z	P>|z|	Coef.	Standardized Coef.	z	P>|z|
Ln labour Hrs	0.034761	0.012845	0.31	0.760	-0.286063	0.110936	-1.70	0.089
Ln seedqnty	0.203718	0.202387	3.60	0.000	0.1495592	0.155614	5.92	0.000
Ln farmsize	0.482837	0.417095	7.02	0.000	0.6773742	0.612836	6.79	0.000
Ln fertilizer	0.077383	0.023799	0.60	0.546	0.4276017	0.137733	2.01	0.044
Ln mech cost	-0.03106	-0.03049	-0.75	0.452	0.2670171	0.274481	2.98	0.003
cons	6.561695		9.54	0.000	4.353439		3.55	0.000
Technical inefficiency								
Sex	-0.051238	-0.012773	-0.41	0.679	0.267017	0.108300	1.18	0.239
Marital status	0.005757	0.010908	0.21	0.832	0.149559	-0.20932	-2.15	0.032
Age	0.061613	0.017741	0.43	0.669	0.615849	0.185996	2.23	0.026
Education	-0.054482	-0.075965	-1.76	0.078	0.090621	0.130824	1.48	0.140
Occupation	-0.000259	-0.000085	-0.02	0.984	-0.08483	-0.29428	-2.91	0.004
Ln Hsize	0.086393	0.047455	1.13	0.258	0.387148	0.575287	2.47	0.013
Social capital network	-0.350536	-0.09885	-1.91	0.057	0.001699	0.000005	0.00	0.997
Land ownership	-0.002162	-0.00046	-0.11	0.911	-0.014749	-0.03354	-0.33	0.743
Extension visit	0.322976	0.092059	2.33	0.020	0.1054485	0.031479	0.32	0.751

Training	0.963574	0.143651	2.57	0.010	1.452322	0.226900	1.87	0.062
Credit	0.045570	0.016271	0.37	0.712	0.211228	0.078990	-0.95	0.344
cons	-1.35866		-1.62	0.104	-4.007366		-1.86	0.064
Usigma cons	-8.56284		-.43	0.671	.7963757		-3.73	0.000
Vsigma cons	-.447581		-5.44	0.000	-32.01302		-0.04	0.968
Sigma u	.013823		0.10	0.921	-.6715359		9.37	0.000
Sigma v	.7994825		24.31	0.000	$1.12 * 10^4$		0.00	0.998
Lambda (λ)	.0172899		0.12	0.905	6006310		$8.40 * 10^7$	0.000
Gamma ($\boldsymbol{\gamma}$) $\boldsymbol{\gamma} = (\frac{\lambda^2}{1+\lambda^2})$	0.029				0.9998			

Author's computation based on NPS data (2014/15)

Discussion for Technical Efficiency

In Tanzania, small-scale maize and paddy farmers have technical efficiency levels of 51.45% and 33.27%, respectively. This indicates the potential for output increase by 48.55% and 66.73% without additional resources. Maize farmers are more efficient than paddy farmers. The efficiency level is low compared that with of other countries. Variations exist because of the different productivity inputs across Tanzania. There is substantial room for improvement in technical efficiencies. Increasing adoption and wise usage of production inputs could result in more

Mathijs and Vranken (2010) emphasise that a firm's inability to achieve optimal production efficiency can be attributed to insufficient adoption of improved technology and a lack of resources to create synergies or reach the technological frontier. Inefficiency may result in cases in which production processes exhibit increasing returns to size and lack adequate funds for acquiring resources. Mwatete et al. (2015) demonstrated that the System Rice Intensification (SRI) technique outperformed conventional practices in rice production, suggesting higher efficiency with SRI. The lower technical efficiency (TE) score for paddy compared to maize can be attributed to paddy's greater capital and labour intensity. Paddy cultivation involves imported inputs and high mechanisation costs, making it less accessible to small-scale farmers with limited resources. Additionally, paddy reliance on rainfall and the need for significant capital investment may hinder small farmers, contributing to lower technical efficiency compared to maize (Pierre, 2000). than a proportionate output increase, as these farmers achieved increasing returns to scale.

Analysing the agricultural production performance of maize and paddies reveals variations in technical efficiency. On average, maize demonstrates higher technical efficiency than paddy, indicating differences in the adoption of production inputs, such as improved seeds, fertiliser, and mechanisation. Both crops exhibit low efficiency levels, which is attributed to the prevalent traditional and subsistence farming practices in rural areas. The impact of education on efficiency is limited, as formal education often lacks practical relevance to farming, pushing individuals towards off-farm employment. These findings align with Edith's (2013) study of Ghana's irrigated rice farms, emphasising the role of exogenous factors in technical efficiency. Input factors such as fertiliser and mechanisation positively affect rice production, while labour has a negative impact. Bempomaa and Acquah (2014) also support the idea of varying efficiency levels in maize farming, with a mean technical efficiency of 67%. This suggests that maize farmers could potentially increase output by 33% without additional resources, highlighting the influence of farm size, labour, and fertiliser on production efficiency.

The findings on paddy technical efficiency (TE) in this study are inconsistent with Hua et al. (2016), who reported a general mean effectiveness of 78.4% in Cambodian rice production, indicating room for improvement in technical effectiveness. Hua et al. attributed variations in TE scores to differing levels of capital expenditure on agricultural machinery, rice harvested area, and fertiliser application across regions. In contrast, Kallika et al. (2010) found TE scores ranging from 49.69% to 97.17% in their study on Thai rice farmers, differing from the current study on paddy TE in mainland Tanzania. Possible explanations include geographical differences, with Thailand being a larger rice producer than Tanzania. Additionally, Musaba and Bwacha (2014) conducted a consistent study on maize production in mainland Tanzania, revealing a mean technical score ranging from 52.2% to 93.2%, suggesting a potential 20.4% increase in maize production through more efficient technology usage.

In conclusion, the research findings on the average technical efficiency score of maize align with similar studies by Nyariki et al. (2015) in Kenya and Kidane et al. (2015) in Tanzania, indicating the influence of factors such as fertiliser use, seeds, and the fragmentation index on technical efficiency. For paddy cultivation, the study supports the Cobb–Douglas production theory, with statistically significant factors including mechanisation cost, quantity of seed, farm size, quantity of fertiliser, and labour. The results highlight the importance of mechanisation in paddy yield realisation, with increased mechanisation costs positively impacting the output. However, an excess of labour per hectare may be currently employed, leading to decreased paddy yield. Additionally, a unit percentage increase in fertiliser usage positively affected paddy yield, although the relationship was not strong. The study's findings are consistent with Ahmadu and Alufohai's (2012) research on the technical efficiency of irrigated rice farmers in Niger State, emphasising the positive impact of seed usage on yield.

Discussion for Determinants that influence technical inefficiency

The analysis indicates a negative relationship between education and inefficiency between maize and paddy production, revealing that educated small-scale maize farmers are more efficient, aligning with findings in studies by Afrin et al. (2017) in Bangladesh, Zhao and Barry (2014) in China, Donkoh et al. (2013) in Ghana, Khai and Yabe (2011) in Vietnam, and Bäckman et al. (2011) in north-western Bangladesh. Education's influence on agriculture production is attributed to skill-building, including literacy for following instructions and numeracy for calculating the correct dosage of inputs. Extension visits positively impact efficiency in maize production, consistent with the results reported by Gebrehiwot (2017) in Ethiopia, Kallika et al. (2010) in Thailand, Edith (2013) in Ghana, and Yannick et al. (2018) in Cameroon. These studies suggest the need for widespread agricultural extension services in rural areas to share knowledge and promote good agricultural practices. However, the findings on extension services differ from studies by Afrin et al. (2017) in Bangladesh, Zhao and Barry (2014) in China, and Bäckman et al. (2011), indicating a potential geographical influence on the relationship between extension visits and inefficiency.

By providing information, extension services help smallholder farmers reduce their transaction costs in accordance with institution theory (Bhardan, 1989). To reduce risk, agricultural extension officers provide vital advice on seed, fertiliser, and crop selection.

Older farmers are less efficient than younger farmers in terms of technical inefficiency in paddy production. This lends credence to the theory that older small-scale farmers are less productive than younger ones, perhaps as a result of lower energy or aversion to new technology. While Zhuo et al. (2013), Ahmadu and Alufohai (2012), and Musaba and Bwacha (2014) concur that older farmers are typically less efficient than younger ones, citing factors like resistance to new practices, Villano and Fleming (2006) found that elderly farmers can improve technical efficiency with experience.

Technical inefficiency in paddy output is negatively affected by marital status, suggesting that married farmers are more productive and efficient. This is in line with Ngeywo and Shitandi's (2015) emphasis on treating singles equally in farming. Ohen and Umar (2018) point out that married farmers' combined family effort results in higher agricultural output.

Technical inefficiency and household size are positively correlated, suggesting that larger households are associated with lower productivity and efficiency. This result is consistent with Zhao and Barry's (2014) theory that households are more motivated to work harder when their dependency ratios are higher. Kidane and Ngeh (2015), on the other hand, contend that larger households provide more labour for farming, contrary to the findings of Ogada et al. (2014), who reported poorer efficiency in homes employing hired labour.

Technical inefficiency is negatively affected by social capital networks, suggesting that membership in these networks improves paddy production efficiency. These networks influence the purchase of inputs such as seeds and fertiliser by facilitating the exchange of knowledge on best farming techniques. This is consistent with Chirwa's (2013) findings, which emphasise how cooperative networks lessen inefficiency and the external effects of social capital networks on non-members.

According to Musaba and Bwacha (2014), cooperative social capital networks reduce technological inefficiency. This investigation confirmed their findings. Social capital networks help farmers in Zambia obtain Farm Input Support Program (FISP)-subsidised inputs. Social capital networks, which emphasise how information transmission lowers transaction costs, risk, and uncertainty, are also consistent with institutional theory. According to Coase (2000), small-scale farmers can increase their production efficiency by having timely knowledge of input prices, which is made possible through social capital networks that provide access to fair markets.

Farmers whose primary occupation is paddy farming show a significant negative association at the 1% level with the stated hypothesis. This implies that those who rely on paddy farming as their main source of income exhibit a decrease in technical inefficiency or increase in efficiency compared to those with alternative livelihoods. Farmers focusing on paddy farming, along with non-farm income, tend to invest more resources, both material and managerial, resulting in higher efficiency. This aligns with Bempomaa and Acquah's (2014) argument that off-farm activities can reduce the technical efficiency of paddy production. Contrary to the positive connections found by Kibirige et al. (2014) and Dlamini et al. (2012), the negative relationship suggests that engaging in non-farming activities may compromise farmers' attention and commitment to crop cultivation, leading to reduced efficiency.

The positive and statistically significant training impact at 10% and 5% for paddy and maize aligns with the research hypothesis. Small-scale farmers attending training exhibit increased inefficiency, lowering technical efficiency, and productivity compared to those without training. Training enhances the decision-making capacity of household heads, particularly in terms of good cultivation practices. Household heads with agricultural training are more efficient than those without. The results support Kuwornu et al. (2013) and Tefaye and Beshir (2014), indicating a positive and significant influence of training on technical efficiency. Strengthening farmer training is crucial for practical field application, in contrast to Al-hassan (2012), who showed a negative and insignificant relationship between training and technical inefficiency. Farmers applying knowledge from training in cultivation practices can reduce inefficiency.

RECOMMENDATIONS

To enhance the technical efficiency of maize and paddy production in Tanzania, it is essential to improve access to agricultural inputs. This can be achieved by ensuring the availability and affordability of improved seeds, fertilisers, and modern machinery through collaboration between the Ministry of Agriculture and non-governmental organizations (NGOs). Such partnerships can significantly address the resource constraints faced by small-scale farmers.

Strengthening extension services is another critical recommendation. Timely and high-quality extension services should be provided to guide farmers on best practices, including appropriate planting times, weed management techniques, optimal fertiliser application, and pest control methods. Field staff should be adequately motivated and equipped to ensure consistent and impactful support to farmers.

Encouraging the establishment and strengthening of farmer-led organizations, such as Mtandao wa Vikundi vya Wakulima Tanzania (MVIWATA), is vital. These organizations play a significant role in disseminating production information and facilitating the collective procurement of inputs. Stakeholders, including NGOs and the Ministry of Agriculture, should actively support these associations to enhance their capacity to improve farmer productivity and output.

Additionally, expanding farmer training programs is crucial for boosting efficiency. Regular training sessions and seminars should be organized to keep farmers informed about modern farming techniques, mechanisation, soil and water management, and climate change adaptation strategies. Such training ensures that farmers remain updated on advancements in agricultural practices.

Improving the education levels of small-scale farmers through adult literacy programs is also recommended. These programs can equip farmers with essential skills for better resource management, enabling them to adopt modern agricultural techniques effectively. Furthermore, fostering partnerships among stakeholders, including government entities, NGOs, and private sector players, can address agricultural efficiency challenges and support sustainable development in the sector

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