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Comparing technical efficiency of maize smallholder farmers in Tabora and Ruvuma regions of Tanzania: a frontier production approach

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ABSTRACT

Technical efficiency was considered in comparing production efficiency of maize crops among smallholder farmers in Tabora and Ruvuma regions respectively, using maximum likelihood estimation (MLE) and ordinary least square (OLS) on Cobb-Douglas production function and OLS on technical inefficiency model in STATA 12 on the National Sample Census of Agriculture 2007/2008 data. Findings indicated that, Tabora smallholder farmers were more technically efficient with mean technical efficiency of 61% compared to 53% of Ruvuma farmers. Actual planted area came as the most important factor that increased maize output and Tractor asset being the most in optimal used factor 'keeping other factors constant', in both regions. From the technical inefficiency model; Age, household size, primary education and inputs costs increased technical inefficiency while credit access, capital assets, good living condition and crop farming as main activity increased technical efficiency in both regions. Thus, the support and sensitization from government and other development partners for agricultural development should be area specific particularly where there is high technical efficiency of the given crop. In optimal use of Tractor among smallholder farmers should be taken as a policy issue; for despite the efforts taken by stakeholders its influence to output attained among smallholders is insignificant.

Contribution/ Originality
Prior research in assessing wellness in using inputs in the country are few and has not considered the effectiveness between the high producing region and the one that has persistence shortages yearly. This paper advances by taking it into account to analyse if output attained yearly reflects the effective use of resources available. It is found that, high produces of the region does not guarantee high level of well use of inputs available and vice versa is true.

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1. INTRODUCTION

In Tanzania, agriculture is the mainstay of the economy and the source of livelihood for most of the poor rural farmers, as it accounts for more than 25 percent of total GDP, and employs about 76.5 percent of the workforce (URT, 2013a). Also, the agricultural sector contributes about 65 percent of raw materials and 30 percent of export earnings (Hepelwa *et al.*, 2013). However, productivity and agricultural output in Tanzania is not encouraging despite the number of policies, plans and initiatives in place that aim at improving agriculture performance (Leyaro and Morrisey, 2013). FANRPAN (2012) notes that these initiatives information is only available to government offices and limited to most of the productive forces, thus, reduces effectiveness of agricultural initiative and programmes despite their initial positive objectives to agriculture.

In Tanzania, maize is grown in almost all regions and is the main cereal and annual grown crop in largest planted area followed by paddy and sorghum (URT, 2012e). More than 20 percent of agricultural GDP comes from maize crop, thus maize is the main grown crop in the country (URT, 2013b). It is proved that, maize is grown by more than 65 percent of the households mainly smallholder farmers who depend on rain fed and traditional methods of maize production (Barreiro, 2012 and MAFAP, 2013). White maize dominates kinds of maize grown and consumed in the country providing more than 55 percent and 35 percent of utilizable calories and protein to the country's population respectively and consumed by more than 85 percent of the population, and the main growers being the smallholders whose income mainly comes from it, while the yellow maize is neglected in general (USDA, 2017).

In the country about 45 percent of the available arable land is covered with maize crop as it is believed to be the most important food crop that influences rural income generation in the country, whereby in 2008, it contributed nearly 50 percent, thus, important for rural development (MAFAP, 2013). Maize remains to be the most produced among cereal crops in the country. In 2016 maize production reached 5500 thousand tons compared to 3429' and 800' thousand tons of paddy and sorghum respectively (FAO, 2017).

Annual cropping is the predominant activity in Tabora region which is heavily labour intensive with a very small amount of permanent crops as a result of uni-model type of rainfall. Maizeis the dominant cereal and annual crop grown by most of the farmers with largest planted area of 44 percent of the total area planted with annual crops (URT 2012a), while tobacco is ranked first annual cash crop (Bucheyeki *et al.*, 2010). Moreover, URT (2012a) notes that groundnut is the most planted oilseed in the region followed by sunflower and soya beans.

Despite the importance of crop production in the region, farmers have been facing fluctuating agricultural produces, thus, they are not sure of the food security (Bucheyeki, 2008). Moreover, smallholder farmers experience sharp yield-decline in maize together with tobacco and groundnut crops grown in the region despite the truth that they are the main source of income and livelihood to smallholder farmers who dominate the region (Katundu *et al.*, 2013).

Ruvuma region on the other hand is one of the southern highland region, economically driven by agriculture particularly crops production by smallholder farmers, other regions are Iringa, Mbeya and Rukwa (Shilda, 2012). Maize is also the dominant annual crop grown by 94 percent of the households. The only annual cash crop grown in wet season is tobacco though there are other cash crops that are permanent like cashew nuts, coffee and banana (URT, 2007b). Currently, most smallholder farmers in the region derive their livelihood from annual crop farming, though the sector in the region is technologically limited. In 2008, manual tools like hand hoe were used by more than 95 percent of the households, this shows dominants of traditional technology in farming (URT, 2012b).

Tabora and Ruvuma regions differ in quantity of maize production over years despite the similar uni-modal rainfall behavior. Ruvuma experience favorable rain while Tabora experience drought like condition due to its location. Ruvuma region outpace Tabora over years as it is part of the major maize producing regions by contributing (9.7%) together with Rukwa (8.7%), Mbeya (11.2%), Iringa (11.4%), Kagera (5.7%), Kilimanjaro (5.5%) and Manyara (7.0%) (FAO, 2015) but this does not say anything on the extent of effectiveness in the application of the inputs available to farmers; thus the study seeks to find the level of technical efficiency between smallholder farmers in the two regions on how well the inputs available to them are used.

1.1. Motivation of the study

As to other Sub Saharan Africa countries, it is noted that, Tanzania agricultural productivity[1] lag behind the potential level of 3.5 to 4 tons/hectare; in food crops production productivity is low around an average of 1.7 tons/hectare in spite of its importance to economic well-being of farmers and nation in general, and to the country's food security (Hepelwa *et al.*, 2013) and (USDA, 2017). Furthermore, it is noted that over years a gigantic increase in maize production in the country is reflected by expansion of planted areas rather than the productivity factor per hectare (FAO, 2015). In addition, only few studies have tried to analyze technical efficiency in production of maize in the country but did not compare the case of two different regions that vary in production trend and earn low income in spite of the importance of the crop in the country and particularly Tabora and Ruvuma regions that results into persistence of poverty to farmers. This, situation creates the need to investigate the present level of technical efficiency in maize production between the two regions, and suggest positive factors of production available to farmers that can be given sensitive attention to increase technical efficiency in producing maize rather than output being over dependant to planted area only.

2. THEORETICAL LITERATURE

Theory of production efficiency can be explained in three ways that are used to measure the level of efficiency in production. These include economic efficiency, technical efficiency and allocative efficiency. Technical efficiency in production occurs when maximum output is achieved given resources, meaning production on the frontier. Allocative efficiency occurs when factors of production are optimally selected and used, thus, economic efficiency is the product of two mentioned. It explains farmer's ability to produce optimal output with minimum cost given technology available (Bravo-Ureta *and Pinheiro* 1997).

Theory of production efficiency is described graphically using the production frontier which explains maximum feasible output given input level. Production efficiency is technical efficiency only when the firm or farmer produces on the frontier and is production inefficient when the firm operates below the efficient boundary. Production efficiency is presented by point 'B' and 'C' in Figure 1 which are points of technical efficient as production lies on the frontier line (OF′) whereas, divergent of production from the frontier line of best production indicates production inefficiency as shown by point 'A' because at the same level of inputs (x) a firm/farmer that/who operate on the frontier at point 'B' achieves potential maximum output (y) compared to the output obtained by firm/farmer at point A, given the same level of inputs (x) producer at B is technically efficient whereas producer at point A is technically inefficient. Technical inefficiency at point A proves possibility of increasing output production to its maximum using the same level of inputs used by producer at point B (Coelli *et al*., 2005).

[1] Productivity is defined as total effectiveness of production inputs used, thus a ratio of output to the inputs given (Girabi and Mwakaje, 2013)

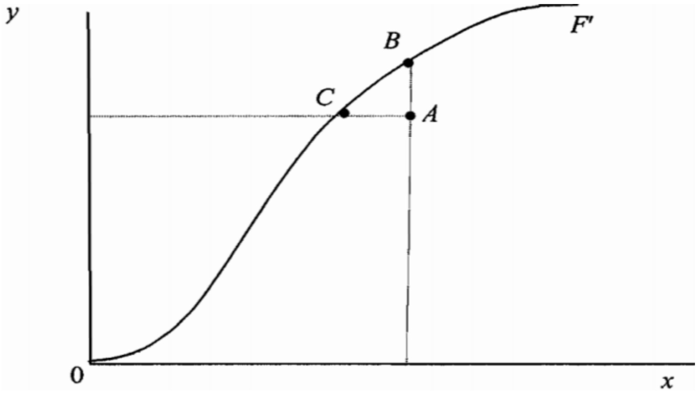

Figure 1: Production/Technical efficient on the frontier F

Source: Coelli *et al*. (2005)

3. EMPIRICAL LITERATURE

In Tanzania, despite the number of policies, plans and initiatives that aim at improving performance of the agricultural sector, only few studies have been conducted on technical efficiency in agriculture to reveal reasons for loss of output from required potentials for relevant policies and initiatives.

Msuya *et al*. (2008) examined productivity variation among smallholder maize farmers in Tanzania particularly Kiteto and Mbozi districts. They employed a stochastic frontier production model to identify determinants of technical inefficiency in cross sectional data of 233 smallholder farmers. They found that land was the most important factor in maize production, and 40 percent of maize output was lost due to technical inefficiency. Smallholder maize farmers' technical efficiency ranged from 0.011 to 0.910 with average of 0.606. Farmers with primary and secondary education, access to fertilizer and household size, use of agrochemicals, use of hand hoe, access to credit, gender(male), use of traditional seed and being member of the farming organization increased efficiency while, plots fragmentation, distance to plots, limited extension service, hired land increase technical inefficiency. Msuya *et al*. (2008) concludes that smallholder farmers operate inefficiently at lower levels; hence policies are needed to improve farmers' extension and credits services to increase productivity and efficiency.

Kibaara (2005) and Chirwa (2007) used a stochastic frontier approach to analyze technical efficiency (TE) and sources of technical efficiency in Kenya and Southern Malawi maize production using the cross-sectional smallholder's household data respectively. Kibaara found that, quantity of fertilizer, seed and labor positively related to maize output yield with seed being the most important factor of production, whilst Chirwa empirical results revealed that, land, capital, labor, fertilizer and seed were positively related to maize output but only labor was the most statistically significant in the production of maize. In Kenya TE ranged from 98.30 %to 8.04 % with average TE of 49 % whilst, in Southern Malawi, it ranged between 8.12 to 93.95 %, with mean TE of 46.23 %. Kibaara found that, hybrid seeds, use of tractors, and number of years in school, male headed households, off-farm income and credit access increased technical efficiency while number of years in school square leads to technical inefficiency, whilst Chirwa found that Seed use and being member of the farmer club were statistically significant in influencing technical efficiency. Both Kibaara and Chirwa recommend on the need for government to promote positive factors of production and efficiency for smallholder farmers are still technically inefficient.

Chiona (2011), applied a two-step approach; (1) Deterministic Envelop Analysis (DEA) and (2) Ordinary Least Square (OLS) in the study of technical efficiency of smallholder maize farmers in Zambia on cross-sectional data on 5,196 farmers. Empirical results show that technical efficiency range from 0.0005 to 1, with an average of 15%. The study found that ripping and ploughed fields are significant in influencing technical efficiency, bunding and zero tillage, cultivating land after rain, female headed family, age below 25 and above 59, use of local seeds, recycled hybrid and primary education both reduces technical efficiency while use of fertilizers, certified hybrid seed, education above primary level, age of 25-59, ownership of livestock, increase in farm size, active farmers and access to extension services increase technical efficiency. The study concludes that, it is possible to increase output without increasing inputs cost.

Geta *et al*. (2013) analyzed productivity and determinants of technical efficiency among maize smallholder farmers of Wolaita and Gamo Gofa zones of Southern Ethiopia using Deterministic Envelopment Analysis (DEA) and Tobit regression on surveyed data of 385 farmers. Empirical results found that, human labor, use of chemical fertilizers, use of oxen power, planting method, hybrid maize seed, farm size and integrated soil fertility were positive and significant in influencing maize productivity while distance to development centre, credit and off farm income were negative and decreased productivity. The study found that the mean technical efficiency among farmers is 40 %. Tobit regression on technical efficiency model indicates that farm size, hybrid maize seed, oxen holding, consumption expenditure and agro-ecology were highly significant in influencing technical efficiency while age, family size, distance to development centre and credits were negative and increased inefficiency. The study recommends on policies to mobilize and motivate youths in agriculture, to increase use of fertilizers, credit and extension services, and provision of training on application of soil fertility management practices.

Scholars of the empirical studies reviewed on production (technical) efficiency, most focusing on the determinants and/or sources of technical efficiency in production of maize. Age, education, extension services, gender, credit access and type of fertilizer and seed are the dominant variables used in assessing sources of technical efficiency in reviewed studies. In addition to these variables, this study takes into account the effects of rate of involvement in agriculture and living condition of the households and influence of input costs to technical efficiency of smallholder farmers. Furthermore, this study adopts a two stage approach that involves; (1) stochastic frontier model to estimate frontier and (2) technical inefficiency model which is estimated by Ordinary Least Square (OLS) approach. An approach is different from DEA and Tobit model employed by Geta *et al*. (2013) in estimating technical efficiency model in the first and second stage respectively.

4. METHODOLOGY

4.1. The study area

The study was conducted in Tabora and Ruvuma regions in Tanzania. Tabora consist of seven districts; Igunga, Urambo, Nzega, Uyui, Sikonge, Tabora urban and Kaliua, with population of about 2.29 million people, whereas Ruvuma consists of six districts; Tunduru, Mbinga, Songea, Namtumbo, Nyasa and Songea urban, with population below 2 million (URT, 2013c). Tabora is found in the Mid-West part of central Tanzania between latitude 4^0 to 7^0 South of Equator and longitude 31^0 to 34^0 East of Green wich Meridian. To the north, it borders Shinyanga region, to the west, Kigoma region, to the south, Rukwa and Mbeya, (URT, 2007a and 2012a). Moderate tropical climate characterizes Tabora region with average temperature of around 23^0C. The temperature tends to fall to 14^0C at night during May to July and reaches the maximum of 20-30^0C during day (MCI[2], 2013). The region experiences rainfall that range between 650 to 1000 millimeters (Tarimo *et al*., 2013).

[2] MCI Means Millennium Cities Initiatives

Ruvuma is found in the Southern Highlands part in Tanzania, it borders Lake Nyasa to the West, Mtwara region to the east, Republic of Mozambique to the south, and Njombe (former Iringa) and Morogoro regions to the North as indicated in Figure 2.1 (URT, 2012b). The region is characterized by having dry and wet seasons. On average the region receives rainfall between 800 to 1800 millimeters. The region has moderate mild temperature of 23ºC on average. During October to November, temperature increases to an average of 30ºC in the lowlands, while around the Matengo highlands in Mbinga, it falls to 13ºC from June to August (URT, 2012b).

4.2. Data type, source, scope and coverage

The study used secondary data from National Sample Census of Agriculture (NSCA), 2007/08 that were collected by National Bureau of Statistics (NBS) in collaboration with the Ministry of Agriculture, Food Security and Cooperatives (MAFC). The census covered both smallholders in rural areas and large scale farms in Tanzania mainland and Zanzibar. Based on the fact that only few large scale farms were partially covered, this study covers only smallholder farmers in Tabora and Ruvuma who cultivate an average of less than 3 acres. This study focused on 2365 and 1710 maize farming households; randomly selected in Tabora and Ruvuma regions respectively. Farming households considered in Ruvuma is less in number to that of Tabora for Ruvuma is taken as a reference point. Its high productions over seasons it gives chance to assume it also have high level of effective use of inputs available. But, the number of observation is expected to decrease because farmers with missing information and outliers were eliminated.

4.3. Economic model

4.3.1. Theoretical specification of frontier production function

Frontier production functions are the functions that behave similar to the theory of production and are estimated econometrically to portray the best maximum output attainable given the resources available to a producer, (Green, 2008). Production on the frontier is efficient and divergent of production from the production efficient curve implies inefficient. Frontier functions are useful in measuring technical and allocative efficiency in which their product gives economic efficiency. Technical efficiency describes the best use of available inputs for maximum produces and the allocative efficiency concerned with optimal use of inputs in production (Mastromarco, 2008). Furthermore, frontier function is useful in understanding and explaining technical change in the production process Føsund and Hjalmarsson (1977).

4.3.2. Stochastic production frontier functions

Stochastic production frontier function was introduced by Aigner *et al*. (1977) and Meeusen and van den Broeck (1977). Stochastic frontier function is more applicable and acceptable to deterministic frontier function initiated by Farrell (1957) and Aigner and Chu (1968) for it is useful in judging how efficiently the technology available is used. It include factors outside control of the producer and those that can be controlled by the producer, thus, preferred by allowing variation across firms to be influenced by both factors (Wan and Battese, 1992) and (Schmidt and Lovell, 1979).

4.3.3. Technical efficiency with stochastic and deterministic frontier functions

Both stochastic and deterministic frontier can be used to estimate technical efficiency but stochastic frontier is more accepted because it takes to account symmetric error which is neglected in deterministic frontier. Only technological inefficiency is considered in deterministic frontier function, thus, $y_i = f(X_i; \beta)$, when estimated becomes $y_i = f(X_i; \beta)TE_i$, where y_i is producer$i$'s output, $f(X_i; \beta)$ is deterministic part and TE_i being producer i's technical efficiency as the ratio of observed output to maximum possible output, that is $TE_i = \frac{y_i}{f(X_i;\beta)}$. Maximum output is achieved when$TE_i = 1$, and$TE_i < 1$ indicatesweakness of the producer to efficiently use the technology and inputs available to produce potential output on the frontier.

On the other hand, stochastic frontier production function that takes to account both technical inefficiency and symmetric errors in the production process is given by $y_i = f(X_i;\beta)\exp(v_i)TE_i$, Where, $f(X_i;\beta)\exp(v_i)$ is the stochastic part that is made up of deterministic part $f(X_i;\beta)$ and symmetric error $\exp(v_i)$ that captures factors outside control of producer. Estimated technical efficiency is$TE_i = \frac{y_i}{f(X_i;\beta)\exp(v_i)}$. Maximum output is achieved when $TE_i = 1$and $TE_i < 1$ implies thatoutput fall below the potential; this is influenced by both inefficiency and symmetric errors that are beyond farmers' control ability (Mastromarco, 2008).

4.3.4. Theoretical specification of stochastic and technical inefficiency models

Input-output points on the technically efficient curve describes the production frontier, thus, farmers' observed input-output combination provides information required for measuring technical efficiency (Pitt and Lee, 1981). The frontier production function which is econometrically estimated is considered, and given by;

$$q_i^* = f(x_i;\beta)\exp(\varepsilon_i) \qquad \text{……………………..} (1)$$

Where q_i^* stands for observed output level of the farmer$i$, $i = 1, 2, \ldots .N, x_i$ is the vector of input quantities used by the farmer$i$, β is a vector of unknown parameters to be estimated, and ε_i is a composed error to farmer i which is made by two components $v_i and u_i$ thus, $\varepsilon_i = v_i - u_i$ (Jandrow *et al*., 1982). Furthermore, v_i is a symmetric error which accounts for factors beyond control of the farmer like weather, and is assumed to be independently and identically distributed as N $(0,\sigma_v^2)$, and u_i is the non-negative random variable that stands for technical inefficiency. In this study u_i follows half normal distribution N $(0,\sigma_u^2)$, though can also follow exponential or truncated-normal distribution.

The maximum likelihood estimation (MLE) of the stochastic frontier (4.5) gives the likelihood variance parameters σ_s^2=$\sigma_v^2 + \sigma_u^2$ which are important in explaining technical inefficiency, where $\sigma_s^2 = sigma^2$ is the farmers' total error variance and (Stata Corp, 2011). According to Aigner *et al*., (1977) as cited in Khai and Yabe (2011), Maximum Likelihood Estimation of the half normal stochastic frontier production function shows the existence of technical inefficiency when the estimated lambda violates the null hypothesis that $\lambda = 0$ (that is,$\lambda > 0$). Thus, the rejection of null hypothesis proves presence of technical inefficiency in the production.

Furthermore, Bravo-Ureta and Pinheiro (1997) argue that one can recognize by how much technical inefficiency is present from λ, by computing γ that ranges between 0 and 1, where,$\gamma = \frac{\lambda^2}{[1+\lambda^2]}$. Likewise, when$\gamma = 0$variation in farm output is caused by factors beyond farmer's control and when γ diverge from zero means farmers self weak effort contribute to farm output variation.

Following Jandrow *et al*. (1982), on the assumption that u_i and v_i are independent of each other, the mean of conditional distribution of u_i given ε_i in the case of half-normal is given by;

$$\mathrm{E}\left(\frac{u_i}{\varepsilon_i}\right) = \sigma_u\sigma_v/\sigma \left[\frac{h\left(\frac{\varepsilon_i\lambda}{\sigma}\right)}{1 - H\left(\frac{\varepsilon_i\lambda}{\sigma}\right)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,$\varepsilon_i\lambda = -u_{i_*}/\sigma_*$, $\sigma_* = \sigma_u\sigma_v/\sigma$,h is standard normal density and $H$is cumulative distribution function.

The combination of ideas of Pitt and Lee (1981) and Jandrow *et al.* (1982) gives technical efficiency of the individual farmer as;

$TE_i = q_i{}^* / (q_i{}^* / exp(-u_i)) = exp(-u_i) = \exp(-E(u_i/\varepsilon_i)) = E(u_i/\varepsilon_i)$ …………………….. (3)

Where, TE_i is technical efficiency of i farmer, u_i is estimated technical inefficiency part, ε_i is an error term in the model, $q_i{}^*$ stands for observed output, $q_i{}^*/exp(-u_i)$ stands for potential output and TE_i and u_i both ranges between 0 and 1.

4.4. Two stage approach

The two stage approach is used in studying frontier production functions despite its contradicting postulation of independent distribution of the inefficiency part. This method starts with regression of the frontier production function to identify presence of technical inefficiency or technical efficiency in the production process. In the second stage, the realized predicted technical inefficiency or technical efficiency model as dependent variable is estimated against independent variables together with a random error to capture sources of technical inefficiency or efficiency in the production process (Battese and Coelli, 1993).

4.5. Empirical Specification for Stochastic and Technical Inefficiency Models

4.5.1. Stochastic frontier production function

The stochastic frontier production function is chosen among the frontiers because it takes into account both symmetric errors and technical inefficiencies in explaining deviations of output from the frontier (Mastromarco, 2008). The technology used in the analysis of the stochastic frontier production function is Cobb-Douglas production function. The method is preferred because its interpretation is simple, and as argued by Khai and Yabe (2011), if the model entails above three exogenous factors, Cobb-Douglas production function is ideal.

From (4.5), the Cobb-Douglas production function can be expressed as:

$$logHoutput = \beta_0 + \beta_1 logHhsize + \beta_2 logArea + \beta_3 Seedtyp + \beta_4 Ferttyp + \beta_5 Tractasset + (v_i - u_i) \quad \ldots\ldots (4)$$

Where, *log Houtput* is log of harvested output of maize or tobacco or groundnuts in kilograms produced by the i^{th} farmer[3] during 2007/2008 agricultural year, *log Hhsize*is log of Household size in numbers that provide labor to the i^{th} farmer, *log Area* stands for log of Actual planted area in acres by the i^{th} farmer, *Seedtyp* represents a type of seed used by the i^{th} farmer (local=0 Improved seed=1), *Ferttyp* stands for a type of fertilizer used by the i^{th} farmer, (traditional=0 or modern fertilizer =1), *Tractasset*, is the Tractor asset used by the i^{th} farmer (Yes=1, No = 0), v_i stands for Factors outside control of the i^{th}farmer like weatherand diseases, and u_i stands for one-sided random error for technical inefficiency of half-normal distribution that is independent of v_i andnon-negative.

4.5.1.1. Cost Saving to an average efficient farmer and least efficient farmer

After estimation of stochastic frontier function, and prediction of technical efficiency, the distribution of technical efficiency is displayed together with possible cost saving that an average and least efficient farmer would have realized when compared to the most efficient counterpart. Cost saving to an average efficient farmer is obtained by taking $\left[1 - \frac{\text{Mean technical efficiency}}{\text{Maximum technical efficiency}}\right] * 100$ and cost saving to the least efficient farmer obtained by $\left[1 - \frac{\text{Minimum technical efficiency}}{\text{Maximum technical efficiency}}\right] * 100$ (Bravo-Ureta and Pinheiro, 1997).

4.5.2. The technical inefficiency model

[3]Farmer(s) stands for farming household(s) whose information obtained from household heads

Production is constrained by inputs and random factors that lead into production fall below the potential frontier output. The fall is highly a result of technical inefficiency which is theoretically identified from stochastic frontier (Battese and Coelli, 1993 and 1995). Identifying technical inefficiency only is not sufficient, thus, the sources of technical inefficiency to solve the problem are needed. Technical inefficiency with respect to independent variables as used by Pitt and Lee (1981) is considered, in addition to this random error is included and other independent factors, therefore technical inefficiency model is given by;

$$U_i = \delta_0 + \delta_1 Age + \delta_2 Hhsize + \delta_3 Edup + \delta_4 Inputcost + \delta_5 Creditaccess + \delta_6 Capitalasset + \delta_7 Livingcond + \delta_8 mainwork + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where, U_i is the Technical inefficiency of the i^{th} farmer, $\delta_0 - \delta_{10}$ is inefficiency parameters to be estimated, *Age* is Age of the farming household head (years), *Hhsize* is the Number of persons in the house who provide labour in farming (numbers), *Edup* is the Education level attained by the head of household in years (1= Primary Education, 0 otherwise), *Inputcost* is the cost incurred in inputs (Tshs) (1=High cost, 0= otherwise), *Creditaccess* stands for farming household access to credit (1= yes, 0= no), *Capitalasset* stands for the bicycle assets available to the farming households(1= yes, 0= No), *Livingcond* stands for living condition of the farming household (1= have iron sheet houses, 0= otherwise), *Mainactivity* stands for farming households who fully engage in farming activities (1=full engagement, 0 otherwise), and ε_i is the error term in the Ordinary Least Square (OLS) of technical inefficiency model.

4.6. Returns to scale

In any production, outputs are expected to vary relative to inputs used. Beattie and Friends (2011) note that, the so called function coefficient is the total percentage change in output relative to percentage change in all inputs. The total percentage change in output is considered as total elasticity of production written as;

$$\varepsilon = E_1 + E_2 + E_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

E_1, E_2 and E_3 are elasticity 1, elasticity 2 and elasticity 3 respectively, and their sum gives total elasticity. Furthermore, quasi elasticity written as $\xi = E_1 + E_2$ is obtained by keeping other factors constant and focusing on only few, in which ε or $\xi > 1$ implies increasing returns to scale (IRT), ε or $\xi < 1$ implies decreasing return to scale (DRT) and ε or $\xi = 1$ implies constant return to scale (CRT) in production.

4.7. Hypothesis of the study

i. There is technical inefficiency in production of maize, tobacco and groundnuts to smallholder farmers in Tabora and Ruvuma region.
ii. Both social and institutional factors are determinants of technical efficiency.
iii. There is slight difference in mean technical efficiency of farmers in the regions.

4.8. Estimation technique

Cobb-Douglas production function and technical inefficiency model are estimated through two stage approach using Ordinary Least Square (OLS) that suggests suitable factors of production, that is inputs output relationship and Maximum Likelihood Estimator (MLE) that estimates the stochastic frontier function using STATA 12 software to detect technical inefficiency, this is in the first stage, while in the second stage, technical inefficiency model is estimated using OLS to capture sources of technical efficiency and inefficiency to the smallholder farming households.

5. EMPIRICAL RESULTS AND THEIR INTERPRETATIONS

4.1. Descriptive statistics

Table 1: Descriptive statistics of maize farmers (farming households)

	Variable	Obs	Mean	Std. Dev.	Min	Max
Tabora	Age	2365	47.2270	15.0386	16	97
	Hhsize	2365	6.4173	3.7266	1	29
	Edup	2365	0.6443	0.4787	0	1
	Inpcost	2365	0.1539	0.3609	0	1
	Creditacc	2365	0.0913	0.2881	0	1
	Capitalasset	2365	0.7403	0.4385	0	1
	Livingcond	2365	0.2431	0.4290	0	1
	Mainwork	2365	0.9133	0.2814	0	1
	Ferttyp	818	0.5562	0.4971	0	1
	Tractasset	2364	0.0143	0.1190	0	1
	Seedtyp	2365	0.1331	0.3398	0	1
	Actual planted Area(acres)	2365	2.5483	2.6267	0.05	40
	Harvested output(Kgs)	2363	1329.873	1728.623	0	23000
Ruvuma	Age	1710	44.3374	14.6502	17	98
	Hhsize	1710	4.7619	2.2536	1	16
	Edup	1710	0.7900	0.4073	0	1
	Inputcost	1710	0.2111	0.4082	0	1
	Creditaccess	1710	0.0450	0.2074	0	1
	Capitalasset	1710	0.4807	0.4997	0	1
	Livingcond	1710	0.4502	0.4976	0	1
	Mainwork	1710	0.5017	0.5001	0	1
	Ferttyp	950	0.9221	0.2681	0	1
	Tractasset	1710	0.0005	0.0241	0	1
	Seedtyp	1710	0.0666	0.2495	0	1
	Actual planted Area(acres)	1710	1.9474	1.8769	0.05	30
	Harvested output(Kgs)	1710	1327.193	2132.463	0	36000

Source: Author's computation using STATA 12 on NSCA 2007/2008

In assessing output inputs relationship, harvested output stands as dependent variable while household size, actual planted area, seed type, fertility type and tractor asset stands as independent variables. Average harvested maize output was 1329.87Kgs and 1327.19Kgs in Tabora and Ruvuma respectively. Average actual planted area was 2.5 acres and 1.9 acres in Tabora and Ruvuma respectively. Inorganic fertilizers were used by 56% and 92% for Tabora and Ruvuma respectively; this indicates that Ruvuma farmers used more of inorganic fertilizers than Tabora farmers. Improved seeds were used by 13% and 6% in Tabora and Ruvuma respectively; this implies that in both regions improved seeds were used in less than 14% and the use of tractors was in low percentage in both regions.

Age, household size, education, input costs, access to credit, capital assets, living condition and main activity are the variables in assessing determinants of technical inefficiency. Average age of the head of household is 47 and 44 years, and average household size is 6 and 5 people per house in Tabora and Ruvuma regions respectively. 64% and 79% of farming households head had primary education, showing that most of household heads in both regions have attained primary level of education. Only 74% and 48% had capital assets such as bicycles for transporting inputs and labor in Tabora and Ruvuma regions respectively. 45% and 24% of the farming households had iron sheet households, most of the remaining percentage had grass leaves and grass and mad houses. Only 50%

and 91% of the households considered crop farming as their main activity in Ruvuma and Tabora regions respectively, revealing that most of the smallholder farmers are crop farmers.

5.2. OLS and MLE of maize stochastic frontier for Tabora and Ruvuma regions

Table 2: OLS and MLE Results from cobb-douglas stochastic frontier function for maize production in Tabora and Ruvuma

		Maize Tabora		Maize Ruvuma	
		OLS	**Stochastic Frontier (MLE)**	**OLS**	**Stochastic Frontier (MLE)**
Variables	Para mets	Coefficient	Coefficient	Coefficient	Coefficient
Constant	β_0	6.08(0.000)***	6.64(0.000)***	5.98(0.000)***	6.93(0.000)***
Log Householde	β_1	0.12(0.005)**	0.14(0.001)***	0.10(0.039)**	0.09(0.042)**
Log Area	β_2	0.83(0.000)***	0.83(0.000)***	0.97(0.000)***	0.95(0.000)***
Seed type	β_3	0.09(0.098)*	0.07(0.145)	0.39(0.000)***	0.39(0.000)***
Fertilizer type	β_4	0.16(0.001)***	0.14(0.002)**	0.28(0.002)***	0.13(0.117)
Tractor asset	β_5	0.07(0.660)	0.09(0.570)	-0.16(0.831)	-0.4(0.534)
$ln\sigma_v^2$			-1.60(0.000)***		-1.84(0.000)***
$ln\sigma_u^2$			-0.64(0.000)***		0.01
σ_v			0.45		0.4
σ_u			0.73		1
$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$			0.73		1.17
$\lambda = \sigma_u/\sigma_v$			1.62		2.52
LR-test of $\sigma_u = 0$			23.62***		81.01***
R-squared		0.47		0.46	
F(5, 807)		144.26			
F(5, 942)				160.23	
Prob> F		0.00***		0.00***	
Prob>Chi2			0.00***		0.00***
Function Coefficient			0.97		1.05
Observation		813	813	948	948

Note: ***, **, * means statistically significant at 1%, 5%, and 10% respectively.Values in the parenthesis are the P-values for the OLS regression and MLE(Maximum likelihood estimation).
Log means logarithm
Function coefficient is the sum of values of logarithm variables
Source: Author's computation using STATA 12 on NSCA 2007/2008

OLS results for both Tabora and Ruvuma regions shows a positive relationship and significance results between maize output level and inputs variables like household size (labor), actual planted area, use of improved seed and use of inorganic fertilizers. Only the use of tractor asset is positve and insignificant in influencing maize output in Tabora and is negative and insignificant in influencing maize output level in Ruvuma, indicating that it is not optimally used to smallholder farmers in both regions. Actualplanted area stands as the most positive and significant factor that influenced maize outputs, meaning that keeping other factors constant, one percent increase in area planted with maize would significantly increase the quantity of maize harvested by 0.97% and 0.83% respectively. Msuya *et al.* (2008) also noted high influence of land (actual planted area) on maize output.

MLE of Stochastic frontier function for both Ruvuma and Tabora indicates the presence of Technical ineffiency in production of maize for both regions. Basing on an idea of Aigner *et al.* (1977) as cited in Khai and Yabe (2011), test for null and alternative hypothesis that $H_0: \lambda = 0$ and $H_1: \lambda > 0$ respectively is perfomed and results of estimated lambda (λ) found to be 1.62 and 2.52 for Tabora and Ruvuma respectively, thus rejecting the null hypothesis that there is no technical inefficiency.

Furthermore, using the formula suggested by Bravo-Ureta and Pinheiro (1997) for testing technical inefficiency value using gamma (γ) that is $\gamma = \frac{\lambda^2}{[1+\lambda^2]}$. Inserting $\lambda = 1.62$and $\lambda = 2.52$ in $\gamma = \frac{\lambda^2}{[1+\lambda^2]}$gives $\gamma = 0.724$ and $\gamma = 0.864$respectively, meaning that about 72.4% and 86.4% of total farm maize output variationin Tabora and Ruvuma regions respectively is due to technical inefficiency. This shows that, variation in farm ouput due to technical inefficiency is greater in Ruvuma than Tabora region by 14 %. This is also proved by the log likelihood ratio test which is greater in Ruvuma (81.01) than that of Tabora (23.62).

OLS estimation results indicates that maize output is explained by independent variables used by 47% and 46% in Tabora and Ruvuma regions respectively (see Table 2). Probability values in OLS and MLE of stochastic frontier is 0.00 in both regions which indicates that the models in general are statistically significant at 1 % level. Furthemore, sum of quasi elastisties in estimated stochastic frontier function is 0.97 for Tabora and 1.05 for Ruvuma, these are the function coefficients which indicate decreasing return to scale (DRS) for Tabora and increasing return to scale (IRS) for Ruvuma maize production as demonstrated in Table 2.

After realizing presence of technical inefficiency in both Tabora and Ruvuma regions, values of technical efficiency were predicted as shown in Table 3.

4.3. Technical efficiency distribution of maize smallholder farmers (farming households) in Tabora and Ruvuma regions

Table 3: Distribution of efficiency

	Tabora Maize Farmers		Ruvuma Maize Farmers	
Efficiency Level	**Frequency**	**% of Farmers**	**Frequency**	**% of Farmers**
< 0.21	12	1.48	65	6.86
0.21-0.40	72	8.86	187	19.73
0.41-0.60	268	32.96	314	33.12
0.61-0.80	411	50.55	326	34.39
0.81-1.00	50	6.15	56	5.91
Observation	813	100	948	100
Maximum TE	0.87		0.87	
Minimum TE	0.15		0.03	
Mean TE	0.61		0.53	

Source: Author estimates using STATA 12 on 2007/2008 NSCA Data

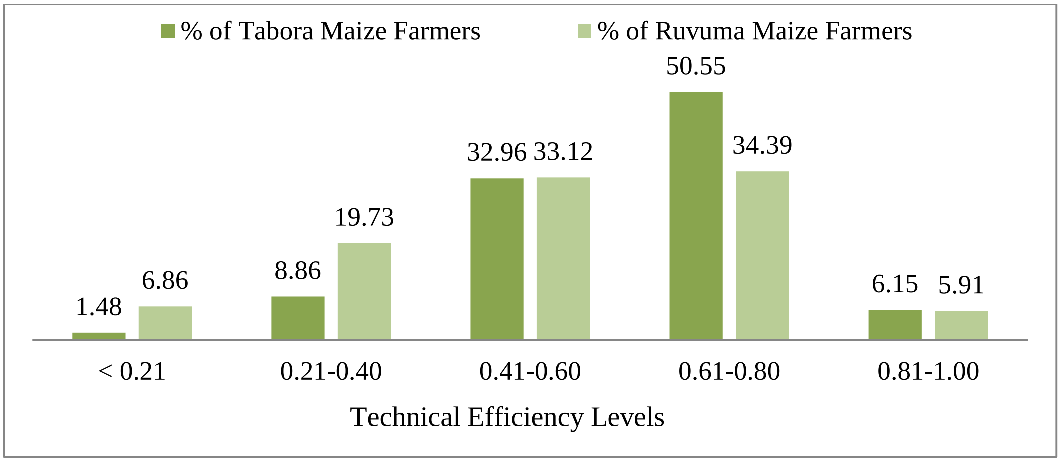

Figure 2: Technical efficiency levels of maize smallholder farmers

Source: Author construction (2014) using NSCA 2007/2008 data

Technical efficiency for maize farmers[4] ranges from 0.15 to 0.87, with mean technical efficiency of 0.61 in Tabora while in Ruvuma ranges from 0.03 to 0.87 with average technical efficiency of 0.53. These results imply that about 39 % and 47 % of maize output lost in Tabora and Ruvuma respectively due to technical inefficiency, this implies that Ruvuma farmers are less efficient to Tabora farmers. This correspond to the level of technical inefficiency observed which is higher for Ruvuma compared to that of Tabora region see the log likelihood ratios.

Applying the average, maximum and minimum technical efficiency values obtained above on maize farmers in Tabora and Ruvuma region, results suggests that, average maize farmer in Tabora region would save 29.89 percent ($[1 - \left(\frac{0.61}{0.87}\right)] * 100$) of costs, and the least efficient maize farmer would save 82.76 percent $\left(\left[1 - \left(\frac{0.15}{0.87}\right)\right] * 100\right)$of costs. In Ruvuma, the most inefficient maize farmers in Ruvuma region would save 96.55 percent equally to($[1 - \left(\frac{0.03}{0.87}\right)] * 100$) while the average maize farmers would realize cost saving of 39.08 percent equally to
$[1 - \left(\frac{0.53}{0.87}\right)] * 100$ when compared to their most efficient counterpart respectively.

Values of technical inefficiency pave the way to realize the factors for technical efficiency or technical inefficiency. As per many scholars, when Technical inefficiency is expressed as independent variable; a negative sign of a dependent variable implies decrease in inefficiency and a positive sign of dependent variable increases inefficiency in the production, and the vice versa is true when technical efficiency is considered as independent variable. Basing on the socio-economic factors available to smallholder farmers; age, education, household size, input costs, credit assets, capital assets (households with bicycles), crop farming as main activity and living condition (households with iron sheet houses) are considered in analyzing factors for technical inefficiency in production so as to be the policy issues to be focused, see Table 4.

[4]Farmer(s) stands for farming household(s)

Table 4: Determinants of technical inefficiency

Technical Inefficiency	Parameter	Tabora	Ruvuma
_cons	δ0	0.4461 (0.000)***	0.4419 (0.000)***
Age	δ1	0.00007 (0.851)	0.0009 (0.029)**
Hhsize	δ2	0.0011 (0.425)	0.0020 (0.497)
Edup	δ3	0.0299 (0.014)**	0.0278 (0.117)
Inpcost	δ4	0.0246 (0.09)*	-0.0040 (0.791)
Creditacc	δ5	-0.0408 (0.002)***	-0.0083 (0.734)
Capitalasset	δ6	-0.0194 (0.17)	-0.0452 (0.001)***
Livingcond	δ7	-0.0209 (0.06)*	-0.0211 (0.104)
Mainwork	δ8	-0.0691 (0.000)***	-0.0138 (0.284)
Prob>F		0.0000***	0.0017***
Observation		813	948

Note: ***, **, * means statistically significant at 1%, 5%, and 10% respectively.Values in the parenthesis are the P-values for the OLS

Basing on equation 4.9 of technical inefficiency model, it shows the possible social economic factors that determine inefficiency of the maize farmers. The results as presented in Table 4 suggests that; Age of the head of household is positive in both regions and statistically significantly at 5% caused inefficiency in Ruvuma region maize farmers, this is possible as heads of farming households becomes older they lose energy hence response to improved agricultural facilities decreases and the supervision over their farms decreases hence inefficiency increase.

Household size that ensures labor in farming activities is positive but insignificant in both regions, suggesting that as labor increases more and more efficiency reaches maximum and start to decreases this is possible due to reality of small farm sizes available to smallholders' farmers. Coefficient of Primary education is positive in both regions and statistically insignificant at 5% in Tabora, suggesting that farmers with primary education produce maize inefficiently; this is possible as many smallholder farmers continue to use outdated methods in farming and mostly produce for subsistence. Chirwa (2007) also found the same result that farmers with primary education influenced production inefficiency in the southern Malawi.

The coefficient of inputs cost is positive and statistically significant at 10 % level in production of maize in Tabora, thus caused inefficiency in the region. This is possible due to the fact that high inputs costs to smallholder farmers it is a burden hence inputs are not used in an optimal level, hence inefficiency. This is shown even by the descriptive statistics which shows that improved seeds were used in less than 14% in both Tabora and Ruvuma regions and also tractors assets were also used in low quantity in both regions.

The coefficient of credit access is negative in both regions and statistically significant at 1% level in Tabora and coefficient of capital assets is negative in both region and statistically significant at1% level in Ruvuma. This suggests that, smallholder farmers with access to credit and those with capital assets like bicycles for carrying inputs and labor increased technical efficiency to maize farmers.

Coefficient of living condition (good living condition) and that of crop farming as main activity are negative in both regions and statistically significant at 10% and 1% level respectively in Tabora suggesting that smallholder farmer's better living condition and those who consider crop farming as their main activity and involves themselves full time in crop farming increased efficiency in production of maize in both regions.

6. SUMMARY, CONCLUSION AND SUGGESTIONS

This study compares technical efficiency of maize production among smallholder farmers in Tabora and Ruvuma regions of Tanzania. Maize crop is considered due to its position in the country as the main annual and staple crop grown in all regions in Tanzania and employs about 75% of the working population; due to this, efficiency in its production has to be given special attention. The study used a two stage approach on National Sample Census of Agriculture (NSCA) 2007/2008 data. In the first stage, OLS and MLE were employed in analyzing the Cobb-Douglas production function, here technical inefficiency was realised to smallholder farmers and actual planted area stand as the most important factor in influencing outputand tractor asset as the most inoptimal factor to maize output in both regions.

In both regions results of technical efficiency indicated the room to increase output using resources available. The mean techinical efficiency were 0.61 in Tabora which is closely to 0.606 obtained by Msuya *et al.* (2008) and 0.53 in Ruvuma region.

In the second stage OLS was used to determine determinants of technical inefficiency. The results shows the need to encourage young people to engage in agriculture for old people decreased efficiency in maize. Credit access, availability of capital assets and good living condition need to be the policy issue for they increased efficiency, so need to be emphasised. Further, government should provide subsdies to inputs to encourage smallholder farmers to use improved inputs for high inputs costs increased inefficiency. In general, policies on agricultural production efficiency related to poverty eradication strategies are to be initiated alsogovernment and other agricultural development partiner should give high priority to a region with high technical efficiency of a given crop to increase output and food security to the country.

This study suggest the use of primary data and panel data for further research for secondary cross Section data were used. Also allocative and economic efficiency approach can be used to analyse efficiency; and the comparison of more than one crop rather than maize only.

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Reference

Aigner, D. J., & Chu, S. F. (1968). On estimating the industry production function. *American Economic Review*, *58*(4), 826-839. *view at Google scholar*

Aigner, D. J., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21-37. *view at Google scholar / view at publisher*

Barreiro-Hurle, J. (2012). *Analysis of incentives and disincentives for maize in the united republic of Tanzania*. Technical Notes Series, MAFAP, FAO, Rome 1-2. *view at Google scholar*

Battese, G. E., & Coelli, T. J. (1993). A stochastic frontier production function: incorporating a model for technical inefficiency effects. *Working Papers in Econometrics and Applied Statistics*, 69, 1-5. view at Google scholar

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effect in a stochastic frontier production function for panel data. *Empirical Economics, 20*, 325-330. view at Google scholar / view at publisher

Beattie, B. R., & Friends, (2011). *Readings in production and consumption economics*. Collected Papers, University of Arizona, 10-11.

Bravo-Ureta, B. E., & Pinheiro, A. E. (1997). Technical, economic and allocative efficiency in peasant farming: evidence from the Dominican Republic. *The developing economies, 35*(1), 49-58. view at Google scholar / view at publisher

Bucheyeki, T. L., Shenkalwa, M. E., Mapunda, X. T., & Matata, W. L. (2010). The groundnut client oriented research in Tabora: Tanzania. *African Journal of Agricultural Research*, *5*(5), 356-362. view at Google scholar

Bucheyeki, T. L. (2008). Perceptions on indigenous fruits processing in sikonge distric in Tanzania: is it sustainable?. *International NGO Journal*, *3*(6), 115-121. view at Google scholar

Chiona, S. (2011). *Technical and allocative efficiency of smallholder maize farmers in Zambia.* MSc (Agricultural Economics) Thesis, University of Zambia, Zambia, 1-49. view at Google scholar

Chirwa, E. W. (2007). *Sources of technical efficiency among smallholder maize farmers in southern-Malawi*. African Economic Research Consortium, Nairobi-Kenya, Research Paper No.172, 9-14. view at Google scholar / view at publisher

Coelli, T. J., PrasadaRao, D. S., O'donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis.* Second edition. Springer Science and Business Media, New York, USA, 1- 4. view at Google scholar / view at publisher

FANRPAN (2012). *Food agriculture and natural resources policy analysis network.* Current and Emerging Youth Policies and Initiatives with a Special Focus and links to Agriculture. Tanzania (Mainland) Case Study Draft Report. 10-33. view at Google scholar

FAO: Food and Agriculture Organization (2015). *The maize value chain in Tanzania*. A Report from the Southern Highlands Food Systems Program. 1-18. view at Google scholar

FAO: Food and Agriculture Organization (2017). *The united rupublic of Tanzania*. Country Brief on Cereal production Report. view at Google scholar

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society, 120*(3), 253-290. view at Google scholar / view at publisher

Føsund, F. R., & Hjalmarsson, L. (1977). *Frontier production function and technical progress: a study of general milk processing in Swedish dairy plants*. Swedish Working Paper No.16, 2-9. view at Google scholar / view at publisher

Geta, E., Bogale, A., Kassa, B., & Elias, E. (2013). Productivity and efficiency analysis of smallholder maize producers in southern Ethiopia. *Journal of Human Ecology*, *41*(1), 67-74. view at Google scholar / view at publisher

Girabi, F., & Mwakaje, A. E. G. (2013). Impact of microfinance on smallholder farm productivity in Tanzania: the case of Iramba district. *Asian Economic and Financial Review*, *3*(2), 227-242. view at Google scholar

Green, W. H. (2008). *The econometric approach to efficiency analysis*. Chapter Two in the Measurement of Efficiency, Oxford University Press, 3-25. view at Google scholar / view at publisher

Hepelwa, A. S., Selejio, O., & Mduma, J. K. (2013). *The Voucher System and the Agricultural Production in Tanzania*. Is the model adopted effective, 1-22. view at Google scholar

Jandrow, J., Lovell., C. A. K., Materov I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function. *Journal of Econometrics*, *19*, 233-238. view at Google scholar

Katundu, M. A., Mhina, M. L., Mbeiyererwa, A. G., & Kumburu, N. P. (2013). *Socio economic factors limiting smallholder groundnut production in Tabora Region*. Draft Report

Presented at REPOA's 18th Annual Research Workshop Held at the Kunduchi Beach Hotel, Dar es Salaam, Tanzania, April 3-4, 1-33. *view at Google scholar*

Khai, H. V., & Yabe, M. (2011). Technical efficiency analysis of rice production in Vietnam. *J. Issaas*, *17*(1), 138-141. *view at Google scholar* / *view at publisher*

Kibaara, B. W. (2005). *Technical efficiency in Kenyan's maize production: an application of the stochastic frontier approach*. Master of Science Thesis, Colorado State University, Fort Collins, Colorado. 10-77. *view at Google scholar*

Leyaro, V., & Morrissey, O. (2013). *Expanding agricultural production in Tanzania*. Scoping study for IGC Tanzania on the National Panel Surveys. International growth centre Report, 1-31. *view at Google scholar*

MAFAP (2013). *Review of food and agricultural policies in the united republic of tanzania: mafap (monitoring african food and agricultural policies) country report series*. FAO, Rome, Italy. 44-191.

Mastromarco, C. (2008). *Stochastic frontier models.* Department of Economics and Mathematics-Statistics University of Salento; CIdE, 10-22. *view at Google scholar* / *view at publisher*

MCI: Millennium Cities Initiatives (2013). *Invest in Tanzania: Focus Tabora.* The Earth Institute, Columbia University, New York, 8-21. Retrieved on Thursday, 6th Feb, 2014, from http://mci.ei.columbia.edu/millennium-cities/tabora-tanzania/tabora-research/.

Meeusen, W., & Van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review, 18*(2), 435-444. *view at Google scholar* / *view at publisher*

Msuya, E. E., Hisano, S., & Nariu, T. (2008). *Explaining productivity variation among smallholder maize farmers in Tanzania*. Paper Presented in the XII World Congress of Rural Sociology of the International Rural Sociology Association, Goyang, Korea in 7-24. *view at Google scholar*

Pitt, M. M., & Lee L. F. (1981). The measurement and sources of technical inefficiency in the Indonesian weaving. *Journal of Development Economics*, 9, North-Holland, 43-58. *view at Google scholar* / *view at publisher*

Schmidt, P., & Lovell, C. A. K. (1979). Estimating technical and allocative inefficiency: relative to stochastic production and cost frontiers. *Journal of Econometrics*, 9, 343-350. *view at Google scholar* / *view at publisher*

SHILDA: Southern Highlands Livestock Development Association of Tanzania (2012). *Understanding the dynamics of forced livestock movements and pastoral livelihoods and future development options in Ruvuma and Lindi regions of Tanzania*. Research Report, 7-41. *view at Google scholar*

Stata Corp. (2011). Stata: release12. *Statistical Software*. College Station, TX: 563-568. *view at Google scholar* / *view at publisher*

Tarimo, B., Mtalo, E., & Liwa, E. (2013). Land use change detected and impact assessment on an agricultural area. *Journal of Sustainable Development, 6*(11), 55-56. *view at Google scholar* / *view at publisher*

URT: United Republic of Tanzania (2007a). National sample census of agriculture 2002/2003. Volume Vr: Tabora Regional Report, 10-98.

URT: United Republic of Tanzania (2007b). *National sample census of agriculture 2002/2003*. Volume Vj: Ruvuma region report 1-94.

URT: United Republic of Tanzania (2012a). *National sample census of agriculture 2007/2008*, Volume Vn: Tabora Regional Report, 13-81. *view at Google scholar*

URT: United Republic of Tanzania (2012b). *National sample census of agriculture 2007/2008*. Volume Vj. Ruvuma region report, 1-91. *view at Google scholar*

URT: United Republic of Tanzania (2012e). *National sample census of agriculture 2007/2008.* Crop National Report, 11-57. *view at Google scholar*

URT: United Republic of Tanzania (2013a). *Public expenditure review (PER).* National Agricultural Input Voucher Scheme (NAIVS) Tanzania. 12-17.

URT: United Republic of Tanzania (2013b). *Ministry of agriculture food security and cooperatives*. National Agriculture Policy, 1-30.

URT: United Republic of Tanzania (2013c). *Population and housing census*. Population Distribution by Administrative Areas. 1-96. *view at Google scholar*

USDA (2017). *Tanzania corn, wheat and rice report grain and feed annual*. USDA GAIN Report, 1-3.

Wan, G. H., & Battese, G. E. (1992). *A stochastic frontier production function incorporating flexible risk properties.* University of New England, Department of Econometrics, 66, 1-3. *view at Google scholar*