Explaining Productivity Variation among Smallholder Maize Farmers in Tanzania

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July 2008

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[1] This paper was presented in the XII World Congress of Rural Sociology of the International Rural Sociology Association, Goyang, Korea 2008 with the title *"An Analysis of Technical Efficiency of Smallholder Maize Farmers in Tanzania in the Globalization Era"*

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Abstract

Using a stochastic frontier production model proposed by Battese and Coelli (1995), the paper estimates the levels of technical efficiency of 233 smallholder maize farmers in Tanzania and provides an empirical analysis of the determinants of inefficiency with the aim of finding way to increase smallholders' maize production and productivity. Results shows that smallholder productivity is very low and highly variable, ranging form 0.01t/ha to 6.77t/ha, averaging 1.19t/ha. Technical efficiencies of smallholder maize farmers range from 0.011 to 0.910 with a mean of 0.606. Low levels of education, lack of extension services, limited capital, land fragmentation, and unavailability and high input prices are found to have a negative effect on technical efficiency. Smallholder farmers using hand-hoe and farmers with cash incomes outside their farm holdings (petty business) are found to more efficient. However, farmers who use agrochemicals are found to be less efficient. Policy implications drawn from the results include a review of agricultural policy with regard to renewed public support to revamp the agricultural extension system, and interventions towards improving market infrastructure in order to reduce the transaction element in the input and output marketing.

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1. INTRODUCTION

Given the scarcity of livelihood options outside agriculture, smallholder maize farmers in Tanzania face multiple challenges, which in the short to medium term can be unraveled by raising productivity[1]. According to R&AWG (2005) and Msuya (2008), increasing productivity is crucial for improving the livelihoods of smallholder farmers, who makes the majority of the rural poor in Tanzania. Msuya (2008: 291) shows that, low productivity is one of the primary causes of low and unstable value added along the value chains leading to a stagnant rural economy with persistence of poverty. Hence, increasing maize productivity is crucial for improving the livelihoods of smallholder farmers in the country.

Studies carried out by Amani, (2004; 2005); Skarstein, (2005); Isinika et al, (2003); MAFC, (2006); Nyange and Wobst (2005); and R&AWG, (2005), shows that smallholder maize productivity in the country is suffering due to the fact that, most smallholders do not practice high-yield farming methods, and produce mainly for subsistence. The Poverty and Human Development Report of 2007 (R&AWG, 2007) showed that 87 percent of Tanzanian farmers interviewed by the research and analysis group under Tanzania's NSGRP said that they were not using chemical fertilizers; 77 percent said that they were not using improved seeds; 72 percent said that they were not using pesticides, herbicides or insecticides (agrochemicals), due to the high costs of agricultural inputs and services. Although studies by Isinika et al (2003) and Skarstein,

[1] Improving marketing linkages and upgrading post-harvest systems are also important

(2005) among others have gone to length to establish additional factors that are holding smallholders from achieving their potentials, none of these studies have been able to address the high variation in productivity among smallholders. According to Ahmad et al (2002) variations in productivity are due to management factors or in other words inefficiency gaps. Therefore, in order to accomplish sustained growth in agriculture, efficiency and productivity differentials have to be reduced. This can be achieved by having an adequate knowledge and understanding of sources/determinants of the smallholder farmers' productivity variations.

Various studies have examined the issues of productivity and technical efficiency of farmers. However, only a handful of them focus on Sub-Saharan Africa (SSA) and of these even fewer focus on Tanzania. Of the few studies that have analyzed efficiency in SSA agriculture include Duvel, Chiche and Steyn (2003); Msuya and Ashimogo (2006); Shapiro and Muller (1977); Tchale and Sauer (2007); and Seyoum, Battese, and Fleming (1998) (see Tchale and Sauer (2007) for a longer list). In Tanzania, little empirical work has been undertaken to quantitatively study the efficiency levels of smallholder farmers with a purpose of identifying ways of improving their efficiency. While Msuya and Ashimogo (2006) determined the technical efficiency of smallholder farmers, they focused on sugarcane production (a cash crop). Shapiro and Muller, (1977) also focused on a cash crop (cotton). No study which we are aware of have determined the efficiency of smallholder farmers in Tanzania and focused on a food crop. Therefore, policy formulation has been hampered by this lack of relevant empirical studies at the farm level. The policy question therefore is: What is the current level of technical efficiency of smallholder maize farmers in Tanzania and what factors influence this current level of efficiency?

Given the importance of food crops[2] and especially maize[3] in Tanzania economy, the estimation of efficiency will facilitate answering questions on the current farm level efficiency in smallholder maize production, and factor(s) that are holding back smallholders from increasing their productivity. An understanding of the relationships between efficiency, policy indicators and farm-specific practices would provide policy makers with information to design programmes that can contribute to increasing food production potential among smallholder farmers, who produce the bulk of the country's food. The main objective of this paper is therefore, to analyze maize production systems in Tanzania, with the aim of finding way to increase production and productivity. Specifically we estimate the levels of efficiency of Kiteto and Mbozi farmers; provide an empirical analysis of the determinants of inefficiency by examining the relationship

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2 Food production dominates Tanzania's agriculture economy. It accounts for about 85 percent of over 5 million hectares cultivated per year.

3 Maize is the major and most preferred staple food crop in Tanzania. It accounts for 31 per cent of the total food production and constitutes more than 75 per cent of the cereal consumption in the country. Maize represents about 30 per cent of the value of crop production in the country and 10 per cent of total value added in agricultural sector respectively (Sassi 2004; Amani 2004: 5; and Isinika, Ashimogo and Mlangwa 2003).

between efficiency level and various farm- and farmer-specific attributes and; considers implications for policy and strategies for improving maize production efficiency.

For meaningful results the paper is guided by the following hypotheses: - (i) Maize smallholder farmers are efficient and have no room for efficient growth; and (ii) Policy variables and/or socio-economic and demographic variables have no significant influence on the efficiency of smallholder maize farmers in the study area. The rest of the paper is organized as follows: The next section presents a short review of technical efficiency (TE) studies among smallholder farmers as a building block for our inefficiency model. The analytical framework, data and empirical model are presented in section 3. The results are discussed in Section 4. Conclusions and the way forward are presented in Section 5.

2. A BRIEF REVIEW OF TECHNICAL EFFICIENCY STUDIES AMONG SMALLHOLDER

Technical efficiency is a component of economic efficiency and reflects the ability of a farmer to maximize output from a given level of inputs (*i.e.* output-orientation). One can trace back the beginning of theoretical developments in measuring (output-oriented) technical efficiency to the works of Debreu (1951 and 1959). Since then however there is a growing literature on the technical efficiency of smallholder farmers' agriculture. Notable works focusing on smallholders include Basnayake and Gunaratne (2002); Barnes (2008); Duvel et al (2003); Shapiro and Muller (1977); and Seyoum et al (1998). The average technical efficiency of smallholders reported in these studies range between 0.49 among maize farmers in Kenya to 0.76 among Tanzania sugarcane farmers. This shows smallholder farmers have low and highly variable levels of efficiency especially in developing countries.

Most studies have associated farmers' age, farmers' education, access to extension, access to credit, agro-ecological zones, land holding size, number of plots owned, famers' family size, gender, tenancy, market access, and farmers' access to improved technologies such as fertilizer, agrochemicals, tractors and improved seeds either through the market or public policy interventions with technical efficiency. Farmers' age and education, access to extension, access to credit, family size, tenancy, and farmers' access to fertilizer, agrochemicals, tractors and improved seeds variables are reported by many studies as having a positive effect on technical efficiency (Amos 2007; Ahmad et al 2002; Kibaara 2005; Tchale and Sauer 2007; and Basnayake and Gunaratne 2002).

Although studies by Amos (2007), Raghbendra, Nagarajan and Prasanna (2005), and Barnes (2008) found the relationship between land holding size and efficiency to be positive, a clear-cut conclusion on the influence of this variable on efficiency has not been reached as discussed in Kalaitzadonakes et al (1992) work. On the other hand, influence of the number of plots on efficiency has been reported by Raghbendra et al (2005) to be negative. This implies land fragmentation (as measured by number of plots) have a negative impact on yields. There are conflicting results on the influence of socio-economic variables such as gender on efficiency. Tchale and Sauer (2007) point out that, while some studies (in Lesotho) report gender of the farmer has no significant influence on efficiency, other studies found that gender plays an important role.

In our inefficient model discussed in 3.2 below, we do not include all the above mentioned variables. For example, 'farmers' access to market' is not included in our model. It is left out due to difficulties associated with smallholder setup in the study area. About 90% of smallholders in the study area sell their maize at home. However, we have included other variables we find important in addressing sources of productivity variability among smallholder farmers. We are assessing the effect of diversification to off-farm activities on efficiency. Due to lack of formal credit facilities, small businesses are used by smallholders to raise money which they need as working capital. This might have a positive effect on efficiency. However, in the long run this practice might not foster specialization leading to a negative impact on efficiency.

According to Skarstein (2005), R&AWG (2005) and Msuya (2007), producer associations are very important in transforming the agricultural sector into one with high productivity and high quality output. While referring to Tanzania, Skarstein (2005: 359) stress that, if the agriculture sector is to be transformed, producer associations (in form of farmers' cooperatives) are needed first and foremost to give the smallholders bargaining power in the input, output and credit markets. Msuya (2007: 2865) and R&AWG (2005: 89) went a step further and showed integrated producer schemes[4] are more suited than

[4] An integrated producer scheme is a setup that operates an integrated system that links production, extension services, transportation, processing and marketing. It has an

cooperatives in assisting smallholder farmers to address most of the constraints they face including low production and productivity. With this in mind we include in the inefficiency model a variable that take into account involvement of smallholders in farmer associations. We also include a district dummy variable to account for agro-ecological and environmental differences between districts, as farming in the study area is greatly influenced by these factors. This will also ensure we reduce biases as a result of omitted variable, which leads to over-estimation of technical inefficiency.

3. ANALYTICAL FRAMEWORK, DATA AND EMPIRICAL MODEL

3.1. Analytical Framework

A stochastic frontier production model proposed by Battese and Coelli (1995) in accordance with the original models of Aigner, Lovell and Schmidt (1977); and Meeusen and van den Broeck (1977) is applied to cross-sectional data to determine the efficiency of the maize smallholder in Tanzania. We consider the stochastic frontier approach because it is capable of capturing measurement error and other statistical noise influencing the shape and position of the production frontier[5]. This technique better suit an agricultural production largely influenced by randomly exogenous shocks as the one

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inbuilt supply chain system that allows the realization of value addition for the benefit of all involved (see Msuya 2007 for an in-depth discussion).

[5] Different (deterministic as well as stochastic, parametric as well as non parametric) techniques to measure relative efficiency are extensively described in the literature, (see e.g. Battese 1992).

found in Tanzania. The technique assumes that farmers may deviate from the frontier not only because of measurement errors, statistical noise or any non-systematic influence but also because of technical inefficiency.

Although today the model has been improved to account for panel data, the model was originally developed to handle cross-sectional data. In Tanzania, Mbelle and Sterner, (1991) applied the model to analyze the importance of foreign exchange in industries. Other notable studies include those of Tyler and Lee, (1979); Battese and Coelli (1995); Taylor and Shonkwiler, (1986); Munroe, (2001); and Raghbendra et al (2005). [See Battese, (1992: 194-204); Ahmad, et al (2002: 644-645) for a detailed review of the empirical application of the model]. Stochastic frontier production functions can be estimated using either the maximum likelihood method or using a variant of the COLS (corrected ordinary least squares) method suggested by Richmond (1974). But here we will consider the maximum likelihood method because availability of software such as the Frontier 4.1 Programme (Coelli, 1996) which has automated the maximum likelihood method.

3.2. Model Specification

Battese and Coelli (1995) proposed a stochastic frontier production function, which has firm effects assumed to be distributed as a truncated normal random variable, in which the inefficiency effects are directly influenced by a number of variables. Given our objectives we apply a Cobb-Douglas production function and the stochastic frontier is thus expressed as:

$$\ln(\text{maize}) = \beta_0 + \beta_1 \ln(\text{Falabour}) + \beta_2 \ln(\text{Hilabour}) + \beta_3 \ln(\text{Land}) + \beta_4 \ln(\text{Material}) + V_i - U_i \quad (1)$$

Where:

ln	Denotes Natural logarithms;
Maize	Total amount of maize harvested (2006/07 season) expressed in tons;
Falabour	Family labour utilized in various farm activities expressed in man-day[6] equivalents;
Hilabour	Hired labour utilized in various farm activities expressed in man-day equivalents;
Land	Land area under maize cultivation in the 2006/07 season expressed in hectares;
Material	Expenditures on intermediate materials (seeds, fertilizer, agrochemicals, fuel, hiring tractor and ox-plough) expressed in Tanzanian shillings[7];
β_i's	Unknown parameters to be estimated;
V_i	Represents independently and identically distributed random errors N (0, σ_v^2). These are factors outside the control of the smallholder; and

[6] Number of labourers * hrs/day * No. days

[7] It was difficult to collect information about fertilizer, seeds and agrochemicals in terms of exact amounts used. Most farmers could precisely remember the cost they incurred but not the exact amount applied due to many plots and varied amount of inputs purchased depending on money availability.

U_i Represents non-negative random variables which are independently and identically distributed as N $(0, \sigma_u^2)$ i.e. the distribution of U_i is half normal. $|U_i| > 0$ reflects the technical efficiency relative to the frontier production function. $|U_i| = 0$ for a farm whose production lies on the frontier and $|U_i| > 0$ for a farm whose production lies below the frontier.

The focus of this analysis is to provide an empirical analysis of the determinants of productivity variability/inefficiency gaps among smallholder maize farmers in Tanzania. Hence knowing that farmers are technically inefficient might not be useful unless the sources of the inefficiency are identified. Thus, in the second stage of this analysis we investigate farm- and farmer-specific attributes that have impact on smallholders' technical efficiency. The inefficiency function can be written as:

$$\begin{aligned} U_i = {} & \delta_0 + \delta_1 \text{ Age} + \delta_2 \text{ Mbozi} + \delta_3 \text{ Noforma} + \delta_4 \text{ Seceduc} + \delta_5 \text{ Primeduc} \\ & + \delta_6 \text{ Useinfer} + \delta_7 \text{ Useinsec} + \delta_8 \text{ Smalbusi} + \delta_9 \text{ Hhsize} + \delta_{10} \text{ Bohiland} \\ & + \delta_{11} \text{ Plonumber} + \delta_{12} \text{ Distplot} + \delta_{13} \text{ Hanhoe} + \delta_{14} \text{ Traseva} + \delta_{15} \text{ Nocoext} \\ & + \delta_{16} \text{ Farmorga} + \delta_{17} \text{ Maizlan} + \delta_{18} \text{ Gender} + \delta_{19} \text{ Credito} + W_i. \qquad (2) \end{aligned}$$

Where:

Age Age of the farmer;

Mbozi Dummy variable for districts, assuming a value of 1 if the farm is located in Mbozi district and 0 if otherwise;

Noforma Dummy variable for smallholder level of education, assuming a value of 1 if the farmer has no formal education and 0 if otherwise;

Seceduc	Dummy variable for smallholder level of education, assuming a value of 1 if the farmer has secondary level education and 0 if otherwise;
Primeduc	Dummy variable for smallholder level of education, assuming a value of 1 if the farmer has primary level education and 0 if otherwise;
Useinfer	Dummy variable showing value of 1 if the smallholder indicated to have used fertilizers, otherwise zero;
Useinsec	Dummy variable showing value of 1 if the smallholder indicated to have used agrochemicals, otherwise zero;
Smalbusi	Dummy variable showing value of 1 if the smallholder owned a small business as addition source of income, otherwise zero;
Hhsize	Household size, (number of people staying together and utilizing scare resources together)
Bohiland	Dummy variable showing value of 1 if the smallholder hired or bought the land under cultivation, otherwise zero;
Plonumber	Measure land fragmentation (number of plots owned by smallholder under maize cultivation);
Distplot	Distance to the plots from homestead expressed in Km;
Hanhoe	Dummy variable showing value of 1 if the smallholder indicated to have used a hand hoe, otherwise zero;
Traseva	Dummy variable showing value of 1 if the smallholder indicated to have used traditional maize seed variety, otherwise zero;

Nocoext	Dummy variable showing value of 1 if the smallholder indicated has never had contact with extension officers, otherwise zero;
Farmorga	Dummy variable showing value of 1 if the smallholder is a member to any farmer organization/association, otherwise zero;
Maizlan	Land area under maize cultivation in the 2006/07 season expressed in hectares;
Gender	Dummy variable showing value of 1 if the smallholder is a male, otherwise zero;
Credito	Dummy variable showing value of 1 if the smallholder has obtained any form of agricultural input credit, otherwise zero;
W_i	An error term that follows a truncated normal distribution; and
δ_i's	Inefficiency parameters to be estimated.

The C-D production frontier function defined by equation (1) and the inefficiency model defined by equation (1) are jointly estimated by the maximum-likelihood (ML) method using FRONTIER 4.1 (Coelli 1996). The FRONTIER software uses a three-step estimation method to obtain the final maximum-likelihood estimates. First, estimates of the α-parameters are obtained by OLS. A two-phase grid search for γ is conducted in the second step with α-estimates set to the OLS values and other parameters set to zero. The third step involves an iterative procedure, using the Davidon-Fletcher-Powell Quasi-Newton method to obtain final maximum-likelihood estimates with the values selected in the grid search as starting values.

3.3. The Data

This study uses data from a Tanzania Maize Value Chain Analysis Survey conducted by the research team (December 2007 – March 2008). The survey covered two regions (Mbeya and Manyara) out of five major maize producing regions in the country. One district each (Kiteto and Mbozi) was selected from Manyara and Mbeya regions respectively. These districts were selected based on their agricultural potential, accessibility, agronomic practices and high levels of maize production. Four villages from each district and 30 farmers per village were randomly selected for detailed interview. A PRA including key stakeholders in each village was conducted for an in-depth understanding of variables used in the two models. The overall sample thus was 240 respondents from the two districts. Out of this sample, about 7 cases were found deficient in displaying reliable farm level information. From the remaining sample (233), 115 and 118 smallholders maize farmers were from Kiteto and Mbozi districts respectively.

4. RESULTS AND DISCUSSION

4.1. Hypothesis Testing and Model Robustness

Before proceeding to examine the parameter estimates of the production frontier and the factors that affect the efficiency of the smallholder maize farmers, we investigate the validity of the model used for the analysis. These various tests of null hypotheses for the parameters in the frontier production functions and in the inefficiency models are performed using the generalized likelihood-ratio test statistic defined by: λ = -2 {log [L

(H_0) – log [L (H_1)]}, where L (H_0) and L (H_1) denote the values of the likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. If the null hypothesis is true, the LR test statistic has an approximately a chi-square or a mixed chi-square distribution with degrees of freedom equal to the difference between the number of parameters in the unrestricted and restricted models.

First we tested the null hypothesis H_0: $\gamma=\delta_0=\delta_1=\ldots=\delta_{19}=0$, which specifies that the technical inefficiency effects are not present in the model i.e. smallholder maize farmers are efficient and have no room for efficiency growth. The hypothesis is rejected as gamma parameter (Table 2) is 0.96 and significant at 5 percent probability level, which means about 96 per cent of the disturbance term is due to inefficiency. Thus the inclusion of the technical inefficiency term is a significant addition to our model. In addition, a stochastic translog production frontier is estimated as a test of robustness in the choice of functional form. The form of this model encompasses the Cobb-Douglas form, so test of preference for one form over the other can be undertaken by analyzing significance of cross terms in the translog form. The ML estimates of the translog production frontier are given in Appendix. Only coefficient of *land* and *material square* shows significant effect on output. But the coefficient of material; product of family and hired labour; product of land and material; and product of hired labour and material are negative. Only one of the parameters in the inefficiency model showed significant effect on inefficiency (Appendix). Furthermore, all cross products have *t*-values less than one or close to zero. This suggests that there are no interactions amongst the variables. Robustness of the estimated models can also be indicated by the value of the log-likelihood function. The model that best fits the data is the one with a higher log-likelihood function. The values of the log-likelihood function for the estimated models are -259.76 and -263.28 for C-D model and translog model respectively. Given that the C–D frontier model best fits the data we conclude it to be more appropriate than translog model specification. The results discussed below (4.2 & 4.3) are only those of the C-D frontier model.

The second null hypothesis which is tested is H0: $\delta_1 = \ldots = \delta_{19} = 0$ implying that the farm-level technical inefficiencies are not affected by the farm- /farmer-oriented variables, policy variables and/or socio-economic variables included in the inefficiency model. This hypothesis is also rejected, implying the variables present in the inefficiency model have collectively significant contribution in explaining technical inefficiency effects for the maize farmers. The results of a likelihood ratio test (LR = 68.39) confirms that smallholders' low and variable productivity predominantly relate to the variance in farm management (efficient use of available resource).

4.2. Production Frontier and Technical Efficiency Estimates

Table 1 shows the results of both the OLS and MLE estimates. In total 25 parameters were estimated in the stochastic production frontier model including 5 in the C-D production frontier model, and 20 in the inefficiency model. Out of the 25 parameters estimated, 14 are statistically significant. Eight are significant at five percent level while the remaining 6 are significant at ten percent level.

Coefficients for land, intermediate materials (material) and hired labour (Hilabour) have expected positive signs and are all significant at five percent level. Land comes as the single most important factor of production with an elasticity of 0.6988. This implies that, *ceteris paribus,* an increase in the extent of land under maize production would significantly lead to increased maize output. Similar results are obtained by Barnes (2008); and Basnayake and Gunaratne (2002) among Scottish cereal producers and Sri Lanka tea smallholders respectively. However, the coefficient in Scottish cereal producers is low (0.289) compared to our results or those of Sri Lanka (1.11). A study by Ahmad et al (2002) on the other hand reports wheat farmers in Pakistan face diminishing returns to scale. This indicates a need for specific (area, crop) policy formulation in addressing low production especially in the developing countries.

Table 1: Parameter Estimates of the C-D Production Frontier

Variables	Parameters	OLS		MLE	
		Coefficient	**t-Ratio**	**Coefficient**	**t-Ratio**
Constant	β_0	-0.1585	-0.6706	0.3523*	1.6452
Ln(Falabour)	β_1	-0.0755*	-2.5162	-0.0527**	-2.4037
Ln(Hilabour)	β_2	0.0177	0.7435	0.0432**	2.2195
Ln(Land)	β_3	0.6968*	9.3802	0.6787**	10.6561
Ln(Material)	β_4	0.0605*	4.6328	0.0558**	4.6821
	σ^2			6.02	
	γ			0.96	
Log-likelihood		-297.27		-259.76	
LR-Test (1)				68.39	

*, ** Significant at 10 and 5 percent probability level respectively

Similarly increase of hired labour and use of intermediate materials will significantly and positively increase smallholders maize output. The coefficient for family labour showed a negative significant value of 0.0522. Most studies reviewed did not decompose the labour variable into family and hired labour, with exception of Basnayake and Gunaratne (2002), who reports positive and significant effect of both family and hired labour on yield. Our result indicates too many family members and or too much time is spent in the maize production process. This might be due to limited opportunities for income generating activities outside agriculture especially in rural areas. Hence, this calls for better utilization of available human resource in rural areas by creating alternative activities (through agricultural based industries).

4.3. Determinants of Inefficiency

The estimated coefficients in the inefficiency model (2) are presented in Table 2. The technical efficiencies of smallholder maize farmers ranged from 0.011 to 0.910 with a mean of 0.606. In other words, on average smallholder maize farmers in the study area incur about 40 percent loss in output due to technical inefficiency (Fig. 1). This implies that on average output can be increased by at least 40% while utilizing existing resources and technology given the inefficiency factors are fully addressed.

It is should be noted that in the inefficiency model (Table 2), variables are included as inefficiency variables; thus a negative coefficient means an increase in efficiency and a positive effect on productivity. The coefficients for farmers' age, education, access to extension services, access to credit, family size and access to fertilizer have the expected sings that corresponds to literature review. The positive and significant coefficient for lack of formal education variable and the negative and significant coefficient for secondary education level indicate that the farmers' education is as an important factor in enhancing agricultural productivity. Unlike previous studies with similar results (Amos 2007; Msuya and Ashimogo 2006), coefficients obtained by this study are large indicating very low level of education among smallholders in the study area. Access to fertilizer and household size also significantly affect technical efficiency positively.

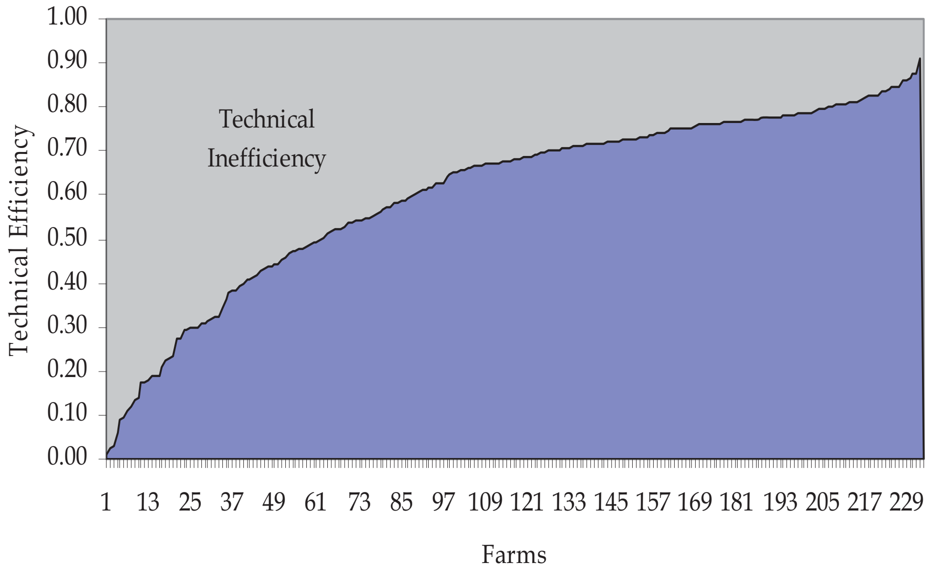


Fig. 1: Cost of technical Inefficiency to Farmers

While one would expect a positive relationship between productivity and economies of scale due to the economies of scale argument and as concluded by previous studies mentioned above (section 2), an inverse relationship between scale and efficiency is found. This can be due to most smallholders practice mixed farming, where crops, trees and livestock are all mixed together in an integrated pattern. This kind of farming is intense and needs close management, if the farmer is to succeed at all. Battered with financial hardships, which makes it difficult to acquire more efficient technologies and or hire labor, the smaller the farm the easier it is for the smallholder to manage well. This agrees with what Peterson (1997) found while studying the effects of farm size on efficiency in ten Corn Belt states in USA. He found that;

> "…*Small family and part-time farms are at least as efficient as larger commercial operations*"….

He also pointed out there was evidences of diseconomies of scale as farm size increases. Therefore, in order to increase production and productivity, further research on the appropriate farm size that will enable smallholders to produce maize more efficiently and not take for granted "*bigger is better"* is highly recommended. Other variables affecting efficiency negatively included number of land plots owned by the smallholder, distance of the plots from homestead and tenancy, implying farm efficiency and thus productivity would significantly increases with consolidation of farm plots to appropriate size that farmers can manage. Consolidation of smallholders' rice farms in the northern part of the country has shown positive results.

Results on gender variable show male farmers to be more efficient. Kibaara (2005) found similar results among maize smallholders in Kenya. However, it should be noted that previous studies as reports by Tchale and Sauer (2007) had found gender to have no significant impact on efficiency. Hence this paper contributes to the on going debate on the role of gender in smallholder efficiency by providing more results showing gender has a significant impact on efficiency.

Table 2: Inefficiency Effects Model

Variables	Parameters	Coefficient	t-Ratio
Constant	δ_0	-3.1553	-0.9169
Age	δ_1	-0.0069	-0.4101
Mbozi	δ_2	3.7944**	2.0517
Noforma	δ_3	3.4720**	2.1427
Seceduc	δ_4	-3.7164*	-1.6680
Primeduc	δ_5	-1.0094	-0.9075
Useinfer	δ_6	-2.6616*	-1.8126
Useinsec	δ_7	4.5176*	1.9280
Smalbusi	δ_8	-3.1617*	-1.9408
Hhsize	δ_9	-0.6710**	-1.9906
Bohiland	δ_{10}	0.3204	0.6214
Plonumber	δ_{11}	0.2339	1.3243
Distplot	δ_{12}	0.0137	0.2753
Hanhoe	δ_{13}	-3.5862*	-1.7595
Traseva	δ_{14}	-1.7922	-1.3959
Nocoext	δ_{15}	1.7679	1.3635
Farmorga	δ_{16}	-1.9722	-1.4070
Maizlan	δ_{17}	0.2538**	2.2426
Gender	δ_{18}	-1.9382*	-1.7342
Credito	δ_{19}	-0.2497	-0.2615

*, ** Significant at 10 and 5 percent probability level respectively

Another interesting result is smallholder farmers using hand hoe are found to be more efficient compared to those using tractor and/or ox-plough. The parameter estimate of means of cultivation variable (hanhoe) is negative and significant at 10 percent level. The current government agriculture policy pushes farmers toward usage of tractors and ox-plough, indicating a mismatch between policies and realities at the farm level. The result obtained could be explained by the fact that, small and fragmented land holdings make it difficult to attain economies of scale for smallholders using tractors. This implies given the current landholdings and smallholder's resource base, investment in highly mechanized agriculture might not necessarily translate to high productivity.

The coefficient for use of agrochemicals variable is positive and statistically significant. This implies that, farmers who use agrochemicals are less efficient compared to farmers who do not spray their farms. This is an interesting result. It can be explained by the fact that, as few smallholder farmers can afford to purchase agrochemicals it means only a handful uses them. Thus, when there is an outbreak of pests or harmful insects smallholders who can spray their farms are still surrounded by many who cannot afford to spray, making the whole exercise ineffective. According to Baffes (2002), many smallholders apply their sprays at the wrong time, using wrong ratios and sometimes with inappropriate chemicals. All of these indicate that, although there are few smallholders using agrochemicals, they are doing so in a manner that negatively affects their productivity. This calls for consideration of alternative pest control mechanism such as Integrated Pest Management (IPM). IPM is an effective and environmentally sensitive approach to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment. This technique is not expensive compared to agrochemicals and uses farmers' local knowledge to combat pests. Hence if planned, promoted and executed well farmers would reduce there cost of production, increase output due to reduced losses and thus productivity.

Farmers with cash incomes outside their holdings, such as in petty trade, are found to be more efficient. The estimated coefficient for running a small business variable is negative and statistically significant at 5 percent level. In the long run too much diversification to off-farm activities does not foster specialization leading inefficiency. Of the two groups of smallholders, Mbozi smallholder farmers are found to engage themselves more in off-farm activities. This might explain why they are found to be less inefficient compared to counterparts in Kiteto district. The coefficient of a variable accounting for district (Mbozi) is positive and statistically significant.

Although not statistically significant, the estimated parameter for farmers' association variable is negative implying a positive effect on productivity. This result agrees with above discussion which show it is important for smallholders to be well organized to have a chance to increase production and productivity.

5. CONCLUSION AND THE WAY FORWARD

The primary objective of this paper is to analyze determinants of productivity variability in smallholder maize production system in Tanzania. This is achieved by determining the efficiency of smallholder maize farmers and identifying the determinants of inefficiency. The paper used a stochastic frontier model, employing cross sectional data covering randomly sampled 233 smallholder maize farmers in two Regions. The results obtained from the stochastic frontier estimation show that inefficiency is present in maize production among smallholders. Sufficient evidence of positive relationship between maize productivity and higher use of intermediate materials such as use fertilizer and seed is present. The results of efficiency analysis show that smallholder farmers are not only producing at a lower level but are also operating relatively farther from the production frontier. Thus there is considerable scope to expand output and also productivity by increasing production efficiency at the relatively inefficient farms and sustaining the efficiency of those operating at or closer to the frontier.

Given technical efficiency is positively associated with level of education, use of inorganic fertilizer, household size, engaging in small business, and usage of hand hoe, policies targeting these variables among others might have a positive impact on smallholders' maize production and productivity. The results also show that the smallholders have varying levels of technical efficiencies across farms, and across districts.

Above discussed results indicate that improvement in provision of agricultural credit (to detour smallholders from off-farm activities) along with extension services are likely to lead to improved smallholder technical efficiency. However, given the escalating prices of inorganic fertilizers (taking the bigger share of the agriculture sector budget), alternatives such as integrated soil fertility management which reduces the effective costs of soil fertility management options are recommended.

Other policy implications drawn from the results include a review of agricultural policy with regard to renewed public support to revamp the agricultural extension system, which has been neglected since the mid 1990s. For all these to take place, it is high time that agriculture sector receive due attention and input from the government so as to advance the country's objectives of growth and poverty reduction.

REFERENCES:

Aigner, D. J., Lovell, C. A. K. and Schmidt, P. 1977. ' Formulation and estimation of stochastic frontier production function models', *Journal of Econometrics* 6: 21-37.

Ahmad, Munir, Chaudhry, Ghulam Mustafa and Iqbal, Muhammad. 2002., Wheat Productivity, Efficiency, and Sustainability: A Stochastic Production Frontier Analysis. *The Pakistan Development Review* 41:4 Part II (Winter 2002) pp. 643–663

Amani, H. K. R. 2004. “Agricultural Development and Food Security in Sub-Saharan Africa Tanzania Country Report” http://www.fao.org/tc/Tca/work05/Tanzania.pdf

------. 2005. “Making Agriculture Impact on Poverty in Tanzania: The Case on Non-Traditional Export Crops”. Presented at a Policy Dialogue for Accelerating Growth and Poverty Reduction in Tanzania, ESRF, Dar es Salaam http://www.tzonline.org/

Ammon Mbelle and Thomas Sterner. 1991. Foreign Exchange and Industrial Development: A Frontier Production Function Analysis of Two Tanzanian Industries *World Development,* Vol. 19, No. 4, pp. 341-347

Amos T. T. 2007. ‘An Analysis of Productivity and Technical Efficiency of Smallholder Cocoa Farmers in Nigeria’, Journal *of Social Science, 15(2): 127 - 133*

Baffes, J. 2002. “Tanzania’s Cotton Sector: Constraints and Challenges in a Global Environment”**,** Africa Region Working Paper Series No. 42

Barnes Andrew. 2008. ‘Technical Efficiency Estimates of Scottish Agriculture: A Note’, *Journal of Agricultural Economics,* Vol. 59, No. 2, 370–376

Basnayake, B. M. J. K., and Gunaratne, L. H. P. 2002. 'Estimation of Technical Efficiency and It's Determinants in the Tea Small Holding Sector in the Mid Country Wet Zone of Sri Lanka', *Sri Lanka Journal of Agricultural Economics* 4: 137-150.

Battese, G. E. 1992. 'Frontier Production Functions and Technical Efficiency: A Survey of Empirical Applications in Agricultural Economics', Agricultural Economics, 7: 185–208.

Battese, G. E. and Coelli, T. J. 1995. 'A model for technical inefficiency effects in a stochastic frontier production function for panel data', *Empirical Economics* 20: 325-332.

Coelli, T. J. 1996. A Guide To Frontier Version 4.1 A Computer Program For Stochastic Frontier Production And Cost Function Estimation. CEPA Working Papers, 96/07, University of New England, Australia. 135pp.

Debreu G. 1951. 'The coefficient of resource utilization, *Econometrica,* 19(3), pp. 273-292.

------. 1959. '*Theory of Value*, New York, Wiley.

Duvel G. H., Chiche Y., and Steyn G. J. 2003. 'Maize production efficiency in the Arsi Negele farming zone of Ethiopia: a gender perspective', *South African Journal of Agricultural Extension* Vol.32: 60-72

Isinika A., Ashimogo G., and Mlangwa J. 2003. AFRINT Country Report – "*Africa in Transition: Macro Study Tanzania"*, Dept of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro

Kalaitzadonakes N.G.,Wu S. and Ma J.C. 1992. 'The relationship between technical efficiency and firm size revisited, *Canadian Journal of Agricultural Economics,* 40, pp. 427-442.

Kibaara B. W. 2005. 'Technical Efficiency in Kenyan's Maize Production: An Application of the Stochastic Frontier Approach', Colorado State University, USA

MAFC. 2006. Kilimo website http://www.kilimo.go.tz/Agr-Industry/Crops-grown-tz.htm

Meeusen, W. and Van den Broeck, J. 1977. 'Efficiency Estimation from Cobb-Douglas Production Function with Composed Error', *International Economic Review* 18: 435-444.

Msuya, E. E. and Ashimogo, G. C. 2006. "An estimation of technical efficiency in Tanzanian sugarcane production: A case study of Mtibwa sugar company outgrower's scheme". *Journal of economic development Vol. (1)* Mzumbe University, Tanzania

Msuya, E. E. 2007. 'Analysis of Factors Contributing to Low FDI in the Agriculture Sector in Tanzania', *Proceedings of the 10th International Conference of the Society for Global Business and Economic Development* (SGBED), Vol. IV, pp 2846-2865

------. 2008. Reconstructing agro-biotechnologies in Tanzania: smallholder farmers perspective. In: *Reconstructing biotechnologies* (Ed. G. Ruivenkamp, S. Hisano, and J. Jongerden), Wageningen Academic Publishers, 2008.

Munroe Darla. 2001. 'Economic Efficiency in Polish Peasant Farming: An International Perspective', Regional Studies, 35:5, 461 — 471

Nyange, D., and Wobst, P. 2005. “Effects of Strategic Grain Reserve, Trade and Regional Production on Maize Price Volatility in Tanzania*: An ARCH Model Analysis*”. Policy Analysis for Sustainable Agriculture Development (PASAD), http://www.pasad.uni-bonn.de

Peterson Willis L. 1997. "Are Large Farms More Efficient?" University of Minnesota, http://ideas.repec.org/p/wop/minnas/9702.html

Raghbendra Jha, Hari K. Nagarajan, and Subbarayan Prasanna. 2005. ‘Land Fragmentation and its Implications for Productivity: Evidence from Southern India’, Australia South Asia Research Centre (ASARC) Working Paper 2005/01

R&AWG. 2005. “Poverty and Human Development Report 2005”, Mkuki and Nyota Publishers, Dar es Salaam

------. 2007. “Poverty and Human Development Report 2007”, Mkuki and Nyota Publishers, Dar es Salaam

Sassi, M. 2004. *“Improving efficiency in the agriculture sector as an answer to globalization, growth and equity: the case of Tanzania*”, Quaderno di ricerca n.4. Pavia, Italy

Seyoum, E. T., Battese G. E. and Fleming E. M. 1998. ‘Technical Efficiency and Productivity of Maize Producers in Eastern Ethiopia: A Case Study of Farmers within and Outside the Sasakawa-Global 2000 Project. *Agricultural Economics* 19: 341-348.

Shapiro K. H. and Muller J. 1977. Sources of technical efficiency: the role of modernization and information, *Econ. Develop. & Cultural Change* 25(2)

Skarstein, R. 2005. “Economic Liberalization and Smallholder Productivity in Tanzania; From Promised Success to Real Failure, 1985–1998, Journal of Agrarian Change, Vol. 5 (3), 334–362

Taylor G. Timothy and Shonkwller J. Scott. 1986. ‘Alternative Stochastic Specifications of the Frontier Production Function In the Analysis of Agricultural Credit Programs and Technical Efficiency’, *Journal of Development Economics* 21: 149-160, North-Holland

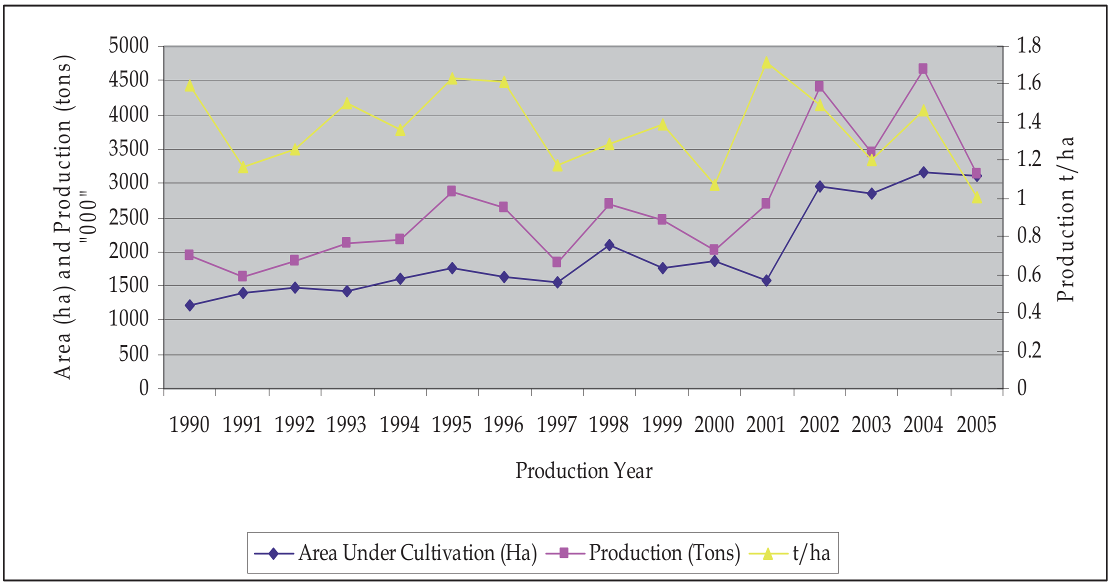
Tchale Hardwick and Sauer Johannes. 2007. 'The efficiency of maize farming in Malawi: A bootstrapped translog frontier’, *Cahiers d’économie et sociologie rurales, n° 82-83,*

Tyler William G. and Lee Lung-Fei. 1979. ‘On Estimating Stochastic Frontier Production Functions and Average Efficiency: An Empirical Analysis with Columbian Micro Data’, *The Review of Economics and Statistics*, Vol. 61, No. 3, pp. 436-438

APPENDIX

Summary statistics for variables in the stochastic frontier production function

Variable	N	Min.	Max.	Mean	Std. Deviation
Maize output 2006/2007 season (t/ha)	233	.01	13.55	1.187	1.207
Family labour utilized (man-day/ha)	233	.00	4470.84	340.294	462.850
Hired labour utilized (man-day/ha)	233	.00	2796.69	127.723	243.444
Area under maize 2006/2007 season (Ha)	233	.22	31.00	3.518	4.019
Intermediate material used (TAS/ha)	233	.00	425633.00	48321.279	66773.528



Maize Production in Tanzania 1990 – 2006

Source: Computation from various official government reports

Maximum likelihood estimates for parameters of the stochastic frontier (translog) and Inefficiency model for maize smallholders

Variables	Parameters	coefficient	Standard error	t-ratio
Frontier Model				
Constant	β_0	0.1339	0.7797	0.1717
Ln(Falabour)	β_1	-0.0011	0.1830	-0.0059
Ln(Hilabour)	β_2	0.0343	0.1449	0.2369
Ln(Land)	β_3	0.6188	0.3024*	2.0461
Ln(Material)	β_4	-0.0564	0.0731	-0.7714
Lnfalabour^2	β_5	-0.0022	0.0137	-0.1613
LnHilabour^2	β_6	0.0094	0.0140	0.6674
LnLand^2	β_7	0.0074	0.0629	0.1172
LnMaterial^2	β_8	0.0101	0.0048*	2.0988
Lnfalabour * LnHilabour	β_9	-0.0071	0.0152	-0.4672
Lnfalabour * LnLand	β_{10}	0.0063	0.0328	0.1928
Lnfalabour * LnMaterial	β_{11}	0.0006	0.0072	0.0837
LnHilabour * LnLand	β_{12}	0.0039	0.0278	0.1384
LnHilabour * LnMaterial	β_{13}	-0.0016	0.0059	-0.2804
LnLand * LnMaterial	β_{14}	-0.0063	0.0176	-0.3595
Inefficiency Model				
Constant	δ_0	-3.4494	3.7146	-0.9286
Age	δ_1	-0.0097	0.0227	-0.4278
Mbozi	δ_2	6.2376	3.7457	1.6653
Noforma	δ_3	3.4085	2.1018	1.6217
Seceduc	δ_4	-5.0086	3.9595	-1.2650
Primeduc	δ_5	-1.8493	1.8373	-1.0065
Useinfer	δ_6	-2.9707	2.0915	-1.4203
Useinsec	δ_7	4.8684	3.2452	1.5002
Smalbusi	δ_8	-2.5411	1.7646	-1.4400
Hhsize	δ_9	-0.2624	0.1991	-1.3179
Bohiland	δ_{10}	0.8839	0.8732	1.0123
Plonumber	δ_{11}	0.8685	0.6363	1.3649
Distplot	δ_{12}	0.0508	0.0576	0.8812
Hanhoe	δ_{13}	-2.7619	1.9197	-1.4387
Traseva	δ_{14}	-3.2895	2.5432	-1.2934
Nocoext	δ_{15}	1.0176	0.9176	1.1090
Farmorga	δ_{16}	-2.0320	1.8153	-1.1194
Gender	δ_{17}	-2.6633	1.8059	-1.4748
Credito	δ_{18}	-1.7928	1.3690	-1.3096