African Journal of Economic Review, Volume 1, Issue 2, July 2013

Sources of Technical Efficiency Among Smallholders Maize Farmers in Babati District, Tanzania

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Abstract

Maize yield in Tanzania has been decreasing in the past few years. The decline has been attributed to many factors. This paper assesses production efficiency and its determinants among maize farmers in Babati district. The paper uses data collected from 122 maize farmers residing in six villages in the study district. A stochastic frontier model has been used to determine the sources of inefficiency among maize farmers in the study area. The results show that the mean technical efficiency score for famers in the study area is 62.3%. This implies that there is a significant room for increasing maize yield in the study area if farmers use the resources at their disposal efficiently. Moreover, the results show that the efficiency of maize farmers in the study area is influenced by farm size, formal education, number of plots owned by the farmer, frequency of contacts with extension officers, and the use of insecticides. It is therefore plausible to argue that improving farmers' access to extension services and important inputs such as insecticides will have a significant influence on maize yield in the study area.

Key words: Smallholders, maize, production efficiency, stochastic frontier

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1. Introduction

Maize is one of the most important food crops in Tanzania. It accounts for about 75% of the total cereal consumption making it one of the strategic crops for food security in the country (Msuya, 2009). The crop provides about 60% of dietary calories to the Tanzanian population (Kaliba, *et al*., 1998). Maize is widely cultivated in the country due to reliable climatic conditions. The crop is grown in almost every region in Tanzania, but it is more important in two agro-ecological zones which include southern and western highlands and the semi - arid lands in the country (WB, 1994).

Maize yield has been decreasing in the past few years. The available data show that the average crop yield per hectare in the country has declined from 1 4071.24 kg in 2007/08 production season to 1 122.536kg in 2009/10 production season (FAO, 2011). The situation has continued to worsen in major producing regions.[4] Available data indicate that yield per hectare has decreased during the same period from 1 823.2kg to 1 265.3kg in Mbeya region, 1584.4kg to 15065.7kg in Ruvuma region, 1556.3kg to 1231.7kg in Iringa region and 1530.2kg to 13363kg in Manyara region (MAFC, 2011).

Babati district which is the main maize producing district in Manyara region has also experienced the problem of decreasing maize yield. Although the area under maize production has increased from 35070ha in 2006/07 to 35280ha in 2009/10, the crop yield per hectare decreased from 1362.5kg in 2006/07 to 1124.8kg in 2008/09 (URT, 2011). This in a way has lead to a situation whereby efforts by farmers to increase area under maize production with a view of increasing output is offset by the decreasing yields per hectare.

Maize yield decline is a pervasive problem, which threatens not only the economic well being of farmers but also the efforts by the government to ensure food security (URT, 2011). This implies that if special attention is not paid to reverse the situation, the country may face severe food insecurity and negative outcomes from rural poverty alleviation efforts by the government through *Kilimo Kwanza*. It follows that, clarifying issues of efficiency and the factors affecting maize production efficiency among maize farmers in the country is of paramount importance. These are important policy issues that need to be understood by policy makers and project planners on the ground for achieving the country's objectives and Millennium Development Goals. The present study is an effort to contribute towards the understanding of the performance of maize farmers in the country and the key drivers for maize farmers' efficiency.

This paper assesses production efficiency and its determinants among maize farmers in Babati district. The paper uses data collected from 122 maize farmers residing in six villages in the study district. A stochastic frontier model has been used to determine the sources of inefficiency among maize farmers in the study area. The results show that the mean technical efficiency score for famers in the study area is 62.3%. This implies that there is a significant room for increasing maize yield in the study area if farmers use the resources at their disposal efficiently. Moreover, the results show that the efficiency of maize farmers in the study area is influenced by farm size,

[4] With the exception of Rukwa region where the average yield per hectare has been increasing.

formal education, number of plots owned by the farmer, frequency of contacts with extension officers, and the use of insecticides.

The remainder of this paper is organized as follows. Section two provides the methodology. Section three reports the estimated coefficients and discusses the results. Section four gives conclusion and recommendations.

2. Methodology

2.1 The Theoretical Model

A production function explains the technical relationship between the inputs and resulting outputs. If estimated empirically from data on observed outputs and input usage, it shows the average level of outputs which can be produced from a given level of inputs (Schmidt, 1985). Several studies have estimated the relative contributions of the factors of production through estimating production functions at either the individual level or aggregate level. These include Cobb-Douglas production functions in fishing industry by Hannesson in1993.

An implicit assumption of production functions is that all firms are producing in a technically efficient manner, and the representative firm therefore defines the frontier. Variations from the frontier are thus assumed to be random, and are likely to be associated with factors of production which are not measured. Contrary the estimation of the production frontier assumes that the boundary of the production function is defined by “best practice” firms. It therefore indicates the maximum potential output for a given set of inputs along a ray from the origin point. Some white noise is accommodated, since the estimation procedures are stochastic, but an additional one-sided error represents any other reason firms would be away from (within) the boundary. Observations within the frontier are deemed “inefficient”, so from an estimated production frontier it is possible to measure the relative efficiency of certain groups or a set of practices from the relationship between observed production and some ideal or potential production (Greene, 1993).

A general stochastic production frontier model can be given by:

$\ln q_j = f(\ln x) + v_j - u_j$ Where q_j is the output produced by firm *j*, x is a vector of factor inputs, v_j is the stochastic (white noise) error term and u_j is a one-sided error representing the technical inefficiency of firm *j*. Both v_j and u_j are assumed to be independently and identically distributed with variance σ_v^2 and σ_u^2 respectively.

2.2 The Empirical Model

This paper uses data from smallholder maize farmers in Babati District to estimate a stochastic frontier production function. It is assumed that the frontier has firm effects which are distributed as a truncated normal random variable, in which the inefficiency effects are directly influenced by a number of variables. Given the objectives this study the model has been specified as follows:

$$\ln(Maizeout) = \beta_0 + \beta_1 \ln(Labour) + \beta_2 \ln(Land) + \beta_3 \ln(Material) + V_i - U_i \quad (1)$$

Where:

$\ln$:	Denotes Natural logarithms;
$Maizeout$:	Total amount of maize harvested in 2009/2010 season expressed in tons;
$Labour$:	Both family and hired labour utilized in various farm activities expressed in man-day equivalents;
$Land$:	Land area under maize cultivation in the 2009/2010 season expressed in hectares;
$Material$:	Expenditures on intermediate materials (seeds, fertilizer, hiring tractor and ox-plough) expressed in Tanzanian shillings
β_i's:	Unknown parameters to be estimated;
V_i:	Represents independently and identically distributed random errors $N(0,\sigma_v{}^2)$. These are factors outside the control of the smallholder; and
U_i:	Represents non-negative random variables which are independently and identically distributed as $N(0,\sigma_u{}^2)$.

Knowing that farmers are technically inefficient might not be useful unless the sources of the inefficiency are identified. Therefore, in the second stage of the analysis the paper investigates farm- and farmer-specific attributes that influence maize farmers' technical efficiency. The inefficiency function has been specified as follows:

$$\begin{aligned} U_i = {} & \delta_0 + \delta_1 Noforma + \delta_2 Hhsize + \delta_3 Plonnumber + \delta_4 Distplot \\ & + \delta_5 Gender + \delta_6 Nocoext + \delta_7 Traseva + \delta_8 Credito + \delta_9 Usefert \\ & + \delta_{10} Usein\sec t + \delta_{11} Hhoe + \delta_{12} Maizeland + W_i \end{aligned} \quad (2)$$

Where:

$Noforma$:	Dummy variable for smallholder level of education, assuming a value of *0* if the farmer has no formal education and *1* if otherwise;
$Use\inf er$:	Dummy variable showing value of *0* if the smallholder indicated to have used fertilizers, otherwise one;

Useinsec: Dummy variable showing value of *1* if the smallholder indicated to have used agrochemicals, otherwise zero;

Hhsize : Household size,

Plonumber : Number of plots owned by smallholder under maize cultivation);

Distplot : Distance to the plots from homestead expressed in Km;

Traseva : Dummy variable showing value of *0* if the smallholder indicated to have used traditional maize seed variety, otherwise One;

Nocoext : Dummy variable showing value of *0* if the smallholder indicated has never had contact with extension officers, otherwise One;

Maizlan: Land area under maize cultivation in the 2009/2010 season expressed in hectares;

Gender : 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 production frontier function defined by equation (i) and the inefficiency model defined by equation (ii) above were 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.

2.2 The Data

The present study was conducted in Babati District, which is one of the five districts in Manyara Region, located below the Equator between 3^0 and 4^0 latitude and longitude 35^0 and 36^0 of Greenwich. Neighbouring districts are Monduli in the North, Karatu in the Northwest, Mbulu in the West, Hanang in the Southwest, Kondoa in the South and Simanjiro in the East. The district population is estimated to be 312 392 people in 2012 of which 158 804 are male and 153 588 (URT, 2013). The study area was regarded best for studying sources of technical efficiency as although in recent years, the study area has experienced some expansion of non-farm activities, still farmers in the district primarily rely on maize production for their livelihoods. Increasing population size and density has also led to fragmentation of landholdings for some families so that the distribution is not homogeneous. Therefore, most of the farmers in the study area operate as smallholders or sharecroppers. Furthermore, accessibility of the area and good agronomic practices were also main drivers for selection of this study area.

Selection of wards and villages for the present study was done with assistance from the office of the District Agricultural and Livestock Development Officer (DALDO) through listing of the respective wards and villages basing on accessibility, good agronomic practices and land management program which is still operating in the district.

Babati district has 18 wards; four wards were selected for the present study as follows, Dareda, Duru, Galapo and Mamire. A total of six villages were selected for the survey (Table 1). There after stratified random sampling was carried out on each ward for selection of respondents who participated in the study *i.e.* people who own maize farm plots of different sizes.

Table 1: Villages Selected from Babati District

Ward	Type	Village
Mamire	Rural	Mamire
Galapo	Mixed	Galapo
		Orongadida
Dareda	Rural	Bermi
		Dareda Kati
Duru	Rural	Duru

3.0 Results and Discussion

Before proceeding to examine the parameter estimates of the production frontier and the factors that affect the production efficiency of the maize farmers, this study investigated the validity of the model $((i)\ and\ (ii)$ used in the analysis. Tests of null hypotheses for the parameters in the frontier production functions and in the inefficiency models were performed using the generalized likelihood-ratio test statistic defined by: $\lambda = -2(\log[L(H_0) - \log(H_1)])$ 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, the null hypothesis which specifies that there are no technical inefficiency effects in the model was tested *i.e.* $H_0 = \gamma = \delta_0 = \delta_1 = ...\delta_{18}$.The hypothesis was rejected as gamma parameter (Table 2) is 0.94 and significant at 5 percent probability level, which means about 94 percent of the disturbance term is due to inefficiency. Thus, the inclusion of the technical inefficiency term is a significant addition to the model. In addition, a stochastic translog production frontier was 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 Table 3.

Table 2: Parameter Estimates of the C-D Production Frontier

		OLS		MLE	
Variables	Parameters	Coefficient	t-ratio	Coefficient	t - ratio
Constant	β_0	-6.8873***	-2.7844	-7.0936***	-3.6963
Ln(Mandays)	β_1	0.07014	0.7093	0.1393**	1.7581
Ln(Land)	β_2	0.4427**	1.8701	0.3293**	1.8643
Ln(Materials)	β_3	0.5204***	2.6825	0.55***	3.6064
	σ^2			1.3967	
	γ			0.94	
Log – likelihood		-143.1195		-129.255	
LR - Test of the one-sided error				27.73	

*, **, ***Significant at 10, 5, and 1 percent respectively

Table 3: MLE for Parameters of the Stochastic Frontier and Inefficiency Model

Variables	Parameters	Coefficient	Standard error	t-ratio
Frontier Model				
Constant	β_0	-88.6749***	1.1766	-75.3668
Ln(Mandays)	β_1	1.2323	2.7624	0.4461
Ln(Land)	β_2	-8.2751***	2.2736	-3.6396
ln(Material)	β_3	12.7257***	2.4241	5.2497
$lnMandays^2$	β_4	-0.1193*	0.1037	-1.1504
$LnLand^2$	β_5	-0.1171	0.2591	-0.4518
$LnMaterial^2$	β_6	-0.5728***	0.1609	-3.5594
LnMandays*LnLand	β_7	-0.1919	0.2731	-0.7029
LnMandays*LnMaterials	β_8	0.1522	0.1735	0.8771
LnLand*LnMaterial	β_9	0.8733**	0.3788	2.3056
Inefficiency Model				
Constant	δ_0	-1.6821**	0.9698	-1.7344
Noforma	δ_1	-0.1818	0.9816	-0.1852
Hhsize	δ_2	0.25894***	0.0928	2.7901
Plonnumber	δ_3	-1.6603***	0.4796	-3.4616
Distplot	δ_4	0.2322***	0.0898	2.5867
Gender	δ_5	2.0357***	0.7228	2.8163
Nocoext	δ_6	-0.2179*	0.1344	-1.6209
Traseva	δ_7	0.7066*	0.4649	1.5196
Credito	δ_8	1.3414**	0.5783	2.3197
Usefert	δ_9	1.4414**	0.8008	1.7999
Useinsec	δ_{10}	-3.2638***	0.1167	-2.7961

*, **, ***Significant at 10, 5, and 1 percent respectively

Table 3, shows that only coefficients of a constant, land, material, mandays square, material square and product of land and material show significant effect on output. But the coefficient of the constant, land, mandays square, material and Material Square are negative. Ten of the parameters in the inefficiency model show significant effect on inefficiency. Furthermore, all cross products have *t*-values less than one or close to zero except the product of land and material. This suggests that there are only interactions between these later 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 -143.1195 and -129.255 for C-D model and translog model respectively. Given that the C-D frontier model best fits the data then it is plausible to argue that it is more appropriate than translog model specification.

The second null hypothesis which is tested is H_0: $H_0 = \delta_1 = ...\delta_{11}$ 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 = 27.73) confirms that farmers' low production efficiency mainly relate to the variance in farm management

3.3 The Production Efficiency and Distribution

The distribution of production efficiency scores of maize farmers in the study vary from 0.008 to 0.92 with the average production efficiency score being 62.3% implying that the average maize farm could increase yield for about 37.7% by improving their technical efficiency. This average TE does not differ significantly with that of 60.6% of Kiteto and Mbozi as presented by Msuya, (2008) and that of Weir (1999) and Weir and Knight (2000) who estimated the mean efficiency levels among Ethiopian cereal crop producers at about 55%. The observed wide variation on technical efficiency is not surprising as similar variation in efficiency among maize farmers has also been observed in Kenya and Malawi with the mean technical efficiency of 49% (range of 8 to 98%) and 46.23% (with a range of 8.12 to 93.95%) respectively. The distribution of efficiency indexes among smallholder maize farmers is depicted in Figure 1.

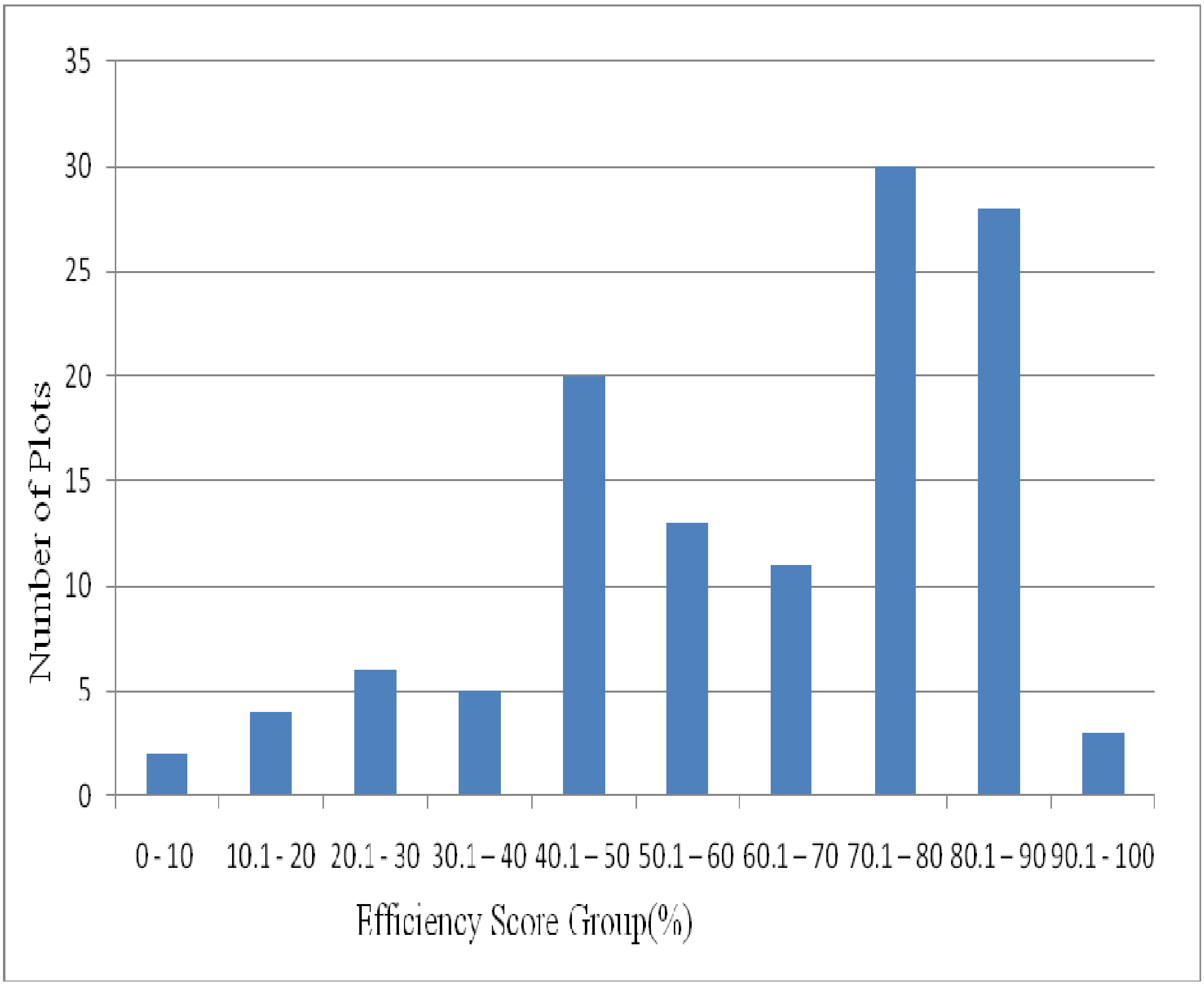

Figure 1: The Distribution of Efficiency indexes among smallholder maize farmers

Note: the term plots as used in this figure refers to decision making units

3.4 Determinants of Inefficiency

This section provides results of the analysis aimed at identifying the key determinants for inefficiency among maize farmers in Babati district. A negative sign on a coefficient means that the variable increases technical efficiency and hence has a positive effect on productivity, while a positive sign reduces technical efficiency. The results on Table 4 reveal that the number of plots owned, number of contacts with extension officer, means of land acquisition, and use of insecticides and the area under maize production have a negative sign and therefore increase technical efficiency. These results appear plausible.

Table 4: Inefficiency Model

Variables	Parameter	Coefficients	Standard error	t- ratio
Constant	δ_0	-1.9908**	1.0951	-1.8179
Noforma	δ_1	-0.4073	1.2358	-0.3296
HHsize	δ_2	0.3087***	0.0953	3.2402
Plonnumber	δ_3	-1.9369***	0.3084	-6.2797
Distplot	δ_4	0.3066***	0.0907	3.3798
Gender	δ_5	2.0867***	0.6255	3.3363
Nocoext	δ_6	-0.2414**	0.1264	-1.9089
Traseva	δ_7	0.8874*	0.549	1.6163
Credito	δ_8	1.3399***	0.544	2.4629
Usefert	δ_9	2.2294*	0.8443	2.6406
Useininsect	δ_{10}	-2.9224***	0.83	-3.5209
Maizeland	δ_{11}	-0.4595**	0.2441	-1.8822

*, **, ***Significant at 10, 5, and 1% respectively

Results on gender (sex) show male farmers are more efficient. This is contrary to results by Masterson (2007) and Tchale and Sauer (2007) who found gender to have no significant impact on efficiency but similar to the results by Msuya *et al.* (2008) among maize farmers in Tanzania and Kibaara (2005) among maize smallholders in Kenya. Consequently, this work is evidence to the ongoing debate on the role of gender in maize farmers' efficiency by providing more evidence showing how gender has a significant impact on efficiency.

The coefficient for use of agrochemicals variable is negative and statistically significant. This implies that, farmers who use agrochemicals are more efficient compared to farmers who do not spray their farms. However, coefficient for the use of fertilizers variable is positive and statistically significant at 10% level of significance. This implies that smallholders who use fertilizers are less efficient compared to those who do not use fertilizers. Since in the present study we have not controlled for differences in soil quality then the negative influence of fertilizer use on efficiency can be attributed to the fact that farmers with farms with low natural soil fertility are more likely to use fertilizers than those who have farms which have higher soil fertility. Therefore, to have a better estimate of the influence of fertilizer usage on efficiency it is important to control for variations in soil fertility among study subjects.

The estimated coefficient of house hold size is positive and significant at 1% level of significance. This implies that maize farmers with large family size tend to be technically efficient in maize production. This result is similar to the results by Oyewo, (2011) for maize farmers in Oyo State who found more family size tend to be technically efficient.

Another result found to be interesting is that; estimated coefficient for the use of traditional seed variety is positive and significant at 10% level of significance. This implies that farmers who use traditional seed varieties are less efficient compared to those who use improved seeds. The results of similar nature were also found by Chirwa, (2007) to maize farmers in Southern Malawi.

4. Conclusion and recommendation

4.1 Conclusions

The main objective of this paper is to determine the sources of production efficiency among maize farmers in Babati, Tanzania. The present study used stochastic production frontier functions in the analysis. The results show that the mean production efficiency among maize farmers is 0.623 indicating that there remains considerable scope to increase maize production by improving technical efficiency.

The farm-specific variables used to explain inefficiencies indicate that those farmers who have high farming experience, large number of farm plots, frequent contacts with extension officers, used insecticides to be more efficient. Due to the gap of 37.7% inefficiency level, resulting from the above mentioned factors there is a need for appropriate policy measures to eliminate this gap. Increasing farm plot size, strengthening extension services, extension materials and farmers training are among the issues that need to be addressed.

4.2 Recommendations

In view of the major findings and conclusions of the present study, the following recommendations are drawn. More efforts are required to improve extension services in the country. The efforts should include training more extension agents and providing more extension materials to the farmers so as to boost the efficiency with which they use the resources at their disposal for producing maize. Moreover, the extension services can be improved by promoting the linkage between farmers, researchers and extension personnel. This will facilitate the flow of information from the researchers to the farmers and vice versa, which is important for the development of relevant technologies. An efficient extension system will ensure proper communication between farmers and researchers, which is important for the developed technologies to reach the end users, and for the researchers to have a clear knowledge of farmers' needs. To achieve this target, the government should enhance the support provided to extension agents and agricultural research institutes.

The present study has found that efficiency can be increased by increasing farm size in the study area. This should be done by emphasizing favorable environment for increasing farm sizes among maize farmers to ensure transformation from agriculture sector dominated by very small farms to a sector dominated by relatively larger farms. The relative increase in farm size will not only enhance food security in the country but will also augment efforts by the government to move its citizens out of absolute poverty.

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