How Efficient Is Maize Production among Smallholder Farmers in Zimbabwe?

Douglas Mugabe
Division of Resource Economics and Management
West Virginia University
domugabe@mix.wvu.edu

Xiaoli L. Etienne
Division of Resource Economics and Management
West Virginia University
xletienne@mail.wvu.edu

Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2

How Efficient Is Maize Production among Smallholder Farmers in Zimbabwe?

Abstract

In this paper, we estimate the efficiency of resource use for maize production among smallholder farmers in Zimbabwe. We collect a total of 176 questionnaires from Mazowe South district, consisting of both A1 (less than 10 hectares of land) and A2 (greater than 10 hectares of land) farms. Findings based on parametric Stochastic Frontier models show that smallholder farmers in Zimbabwe are not efficiently utilizing their available agricultural resources when producing maize. The average technical efficiencies are only 36.75% and 38.6% for A1 and A2 farms, respectively. About 60% of A1 and all A2 farmers have technical efficiency scores between 0.3 and 0.5. In the non-parametric analysis, however, we find a much higher technical efficiency for both types of farms, over 60% and 75% for A1 and A2 farms, respectively. Still, these numbers are lower than those found in other countries. Among other factors examined, attaining tertiary education and access to extension services by the head of the household can significantly improve production efficiency.

Keywords: Resource Use Efficiency, Technical Efficiency, A1 and A2 smallholder farmer, Stochastic Frontier model, Inefficiency, Data Envelopment Analysis

1. Introduction

Agricultural production is the primary economic sector in Zimbabwe and represents the livelihood of most of the poor in the country. The fast track land reform program (FTLRP) implemented by the Zimbabwean government in 2000 resulted in institutional changes of the agricultural industry that affected the social and economic status of the country. Prior to FTLRP, most arable land in Zimbabwe was held by well-organized large commercial farms that were able to efficiently allocate available resources in agricultural production. Under the FTLRP, A1 and A2 farm models were created, replacing large commercial farmers with rural communal farmers. A1 model farms are small plots (usually less than 10 hectares of arable land) with an average of 6.8 hectares allocated to farmers, while A2 model are farms with plots typically above 10 hectares grouped into small, medium and large farms (Cliffe et. al 2014; Mugabe et. al, 2014). Smallholder farmers are often characterized with little or no investment in agricultural production due to insecurity in the land tenure systems, market imperfections, and very limited access to agricultural input and output markets, credit, and off farm employment. As a result, it is reasonable to expect that agricultural production efficiency has deteriorated after the FTLRP, as the law replaced efficiently-run commercial farms with smallholder farms that lack the ability to efficiently use the available resources. Currently, more than 35% of arable land have been allocated to smallholder farms after FTLRP with more than 161,500 families resettled of which 145,000 are A1 and 16,500 are A2 farmers (Scoones et. al 2011 and Pallotti et. al, 2015).

Only a handful of studies have evaluated the efficiency of resource use in agricultural production in Zimbabwe after FTLRP. Bangwayo-Skeete et al (2010) estimated a stochastic frontier efficiency model using the Heckman sample selection procedure, and found that FTLRP beneficiaries are more efficient than the communal farmers who applied for the program but were rejected. Zikhali (2008) evaluated the impact of FTLRP on productivity and social conservation investment, and found that the FTLRP did not only create some insecurity among the beneficiaries but also had a negative effect on investments in soil conservation. Those households that believed investing in land enhanced tenure security invested significantly more and their perceptions of tenure security depended positively on investment levels, supporting the contention that households invest in long-term land-related investments to enhance security of tenure.

Mushunje et. al (2003) examined technical efficiency of cotton farmers from Mutanda resettlement scheme of Manicaland province, and found anj average of 71% technical efficiency which declines with farm size and education level and increases with family size and age of household head. Obi et. al (2011) also analyzed the performance of resettled smallholder farmers under limited mechanization and FTLRP, and found that mechanization, availability of land and access to production resources are important determinants of farm performance under Zimbabwe's FTLRP.

However, little attention has been paid to the resource use efficiency of maize production in Zimbabwe. Maize is the staple crop in Zimbabwe and is used for both household consumption and income generation. In recent years, maize production in Zimbabwe has steadily declined. Data from the Food and Agriculture Organization (FAO) show that Zimbabwe was a net exporter of maize prior to 2001, and a net importer since. It is estimated that between 650 and 700 thousand tons, or about one third of the total domestic maize demand, are to be imported for the 2015/16 marketing year (FAO, 2015). Market analysts and academic researchers often attribute Zimbabwe's decline in agricultural output to the 2000 FTLRP that resulted in a significant number of smallholder farms lacking the skills and ability to efficiently produce agricultural crops compared to the previously large scale commercial farms.

So, how efficient is maize production among smallholder farms in Zimbabwe? In other words, are A1 and A2 farmers able to combine inputs and outputs in the optimal proportion in light of prevailing prices (Francesco, 2009)? Or by how much has A1 and A2 farm production deviated from the optimal production frontier? Regarding efficiency, Lovell (1993) emphasized that efficiency indicates productivity of a product unit which can be measured by the ratio of its output to input. Greene (1997) went on to say that 'producers are efficient if they have produced as much as possible with the inputs they have actually employed, producing that output at minimum costs'.

The objective of this research is to evaluate production performance (technical efficiency) of smallholder farming in Zimbabwe after the FTLRP. Answering this question has broad implications beyond maize production in Zimbabwe as similar questions are likely to exist in many underdeveloped countries, particularly in Africa. Specifically, this study seeks to address the following questions: (1) is land, labour or capital significant in explaining small holder A1 farmer maize production; (2) are small holder farmers efficiently producing maize; and (3) what are the determinants of technical efficiency in maize production among smallholder farmers in Zimbabwe?

In the following analysis, we first employ a Stochastic Frontier (SF) model to evaluate how far maize production among smallholder farms deviates from the efficient production frontier. Such parametric SF analyses have been widely used in literature to evaluate the efficiency of agricultural production in various countries, Nyekanyeka 2011, Abu et al 2009 and Asogwa et al 2011, among others. However, parametric SF analyses have often been criticized for imposing potentially inappropriate production technology in the analysis, and the possibility of introducing estimation errors due to incorrectly-specified error structures. To address such concerns, we next employ a nonparametric approach, namely Data Envelopment

Analysis (DEA), to re-estimate the production efficiency among smallholder farms in Zimbabwe as a robustness check. To identify the determinants of production inefficiency, we further allow the inefficiency score derived from the error term from the Stochastic Frontier model to depend on household characteristics and other factors related to maize production.

We find the average technical efficiency to be 36.75% and 38.6% for A1 and A2 farms when using the parametric Stochastic Frontier model, respectively. This suggests a rather low performance level among smallholder farms. About 60% of the A1 farmers and all of the A2 farmers have a technical efficiency score between 30% and 50%. The low efficiency score found for the majority of the farms suggests that significant cost reduction or output growth can be attained if land, capital, or labour are used more efficiently. In the non-parametric analysis, however, we find a much higher technical efficiency for both types of farms, over 60% and 75% for A1 and A2 farms, respectively. Still, these numbers are lower than those found in other countries. Among other factors examined, attaining tertiary education and access to extension services by the head of the household can significantly improve production efficiency.

2. Estimation Procedures

In a seminal paper, Farrell (1957) introduced a framework to measure production inefficiency that uses the frontier production function as a benchmark. Earlier studies measuring technical efficiency for cross-sectional data primarily rely on the deterministic frontier approach that assumes any deviations from the production frontier are a result of inefficiency. Aigner et. al (1977) and Meeusen et. al (1977) independently developed the stochastic frontier approach so that deviations from the production frontier are a result of both technical inefficiency and random errors that cannot be controlled by individual producers.

Both approaches have strengths and weaknesses. Resti (2000) argues that there is no clear advantage of one approach over the other. Regardless, studies have found that the deterministic frontier approach usually result in larger technical inefficiency. Below, we consider both a Stochastic Frontier (SF) model (Parametric Approach) and Data Envelopment Analysis (non-parametric approach) to evaluate the technical efficiency of maize production in Zimbabwe.

2.1 Parametric Stochastic Frontier Model

Assuming a Cobb-Douglas production function, the stochastic frontier model proposed by Aigner et. al (1977) and Meeusen et. al (1977) can be described as:

(1)
$$Y_k = A_k \prod_{i=1}^{I} X_{ik}^{b_i} \mathcal{E}_k$$

Where Y_k is the output of maize produced by household *k*, X_i is a vector of input variables including labour, capital, and land allocated to maize production, and A_k is the total factor productivity. The error term $\mathcal{E}_k$ can be decomposed into two elements: one measures the idiosyncratic disturbance due to measurement errors and other classical noises (V_k), and the other element measures a one-sided disturbance that captures technical inefficiency ($-U_k$) for each farmer *k*. The random error term V_k is typically assumed to follow a two-sided normal distribution. Equation (1) can be linearized by taking logs of both sides of equations:

(2)
$$LnY_k = b_0 + b_1 LnX_{1k} + b_2 LnX_{2k} + b_3 LnX_{3k} + Ln\mathcal{E}_k$$

Based on the production functions in equations (1) and (2), the technical efficiency score of farm *k* can be estimated as in equation (3):

(3)
$$\boldsymbol{TE_k = -\frac{Y_k}{exp\big(f(X_{ik}, \beta) + \nu_{\ k}\big)} = exp(-\mu_{\ k})}$$

Where TE_k is the technical efficiency of household k, $f(X_i, \beta)$ is the quantity that can be produced with X_i Technology described by the parameters β, and $exp(V_k)$ is the stochastic component of the production function which accounts for the statistical noise in the production process.

2.2 Non-Parametric Data Envelopment Analysis

Parametric SF analyses are often criticized for imposing potentially inappropriate production technology in the analysis, and the possibility of introducing estimation errors due to incorrectly-specified error structures. To address such concerns, we next employ a nonparametric approach, namely Data Envelopment Analysis (DEA), to re-estimate the production efficiency among smallholder farms in Zimbabwe as a robustness check. Unlike SF analysis, DEA does not impose a specific functional relationship between input and output, and does not assume specific statistical distribution of the error structure. However, one drawback of DEA is that it does not allow for idiosyncratic disturbances, instead attributing all factors to inefficiency. Non-parametric analyses (DEA) have been widely used in literature to evaluate performance or efficiency of agricultural production in various countries, including Oguntade et al (2012), Bhatt et al (2014), among others.

To measure the relative efficiencies of smallholder farms with land, labour and capital as inputs when producing maize, the DEA approach assigns weights to inputs of the farmer that gives the best efficiency level that is possible. The DEA approach then computes piece-wise frontier over points, and the scores of efficiency of each farm depends on the distance from the frontier. The analysis employs a linear programming model to calculate efficiencies without parameterizing the technology. Charnes et al (1978) contended that the objective of DEA is to measure producer performance relative to the best observed practice in the sample under restriction of returns to scale, convexity of the set of feasible inputs and outputs and strong disposability of inputs and outputs. The linear programming model can be summarized in equations (4) to (8):

(4) *Maximize* $\mu Y_k / \upsilon X_k$ $for\ each\ value\ of\ k = 1,2 \ldots., N$

(5) *Subject to:* $\mu Y_j / \upsilon X_j \leq 1\ ; j = 1,2 \ldots \ldots, N$

(6) $\mu_i, \upsilon_i \geq 0$

(7) $\upsilon X_k = \sum_i \upsilon_i X_{ki}$, *i=1,23,*

(8) $\mu Y_j = \sum_i \mu_i Y_{ji}$, *i=maize;* $j = 1,2 \ldots \ldots, N$

2.3 Factors Affecting Technical Efficiency

After obtaining the technical efficiency estimates for each farmer, we next examine the factors that affect their production performance, as in equation (9):

(9) $U_k = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 \ldots \ldots \ldots \delta_n Z_n + W_i$

where δ_0, … δ_n are the parameters to be estimated, Z_n is a vector of farmer and household socio-economic characteristics, including farmers' location, gender of household head, marital status of household head, age of household head, educational level of household head, household size, access to extension services, and other crops grown on the farm. All variables except age and household size were captured as dummy variables. W_i is the iid random error.

3. Data

A survey was conducted in 2014 in ward 14 of Mazowe South district. The ward is bordered by Glendale, Bindura and Chiweshe communal lands. A total population sampling was done from the 3 purposively chosen sub areas namely Longcroft, Davaar and Sweetvalley located in the same agricultural geographical typological area. The purposive sample drawn contains 176 units, constituting 113 A1 and 63 A2 households. Longcroft area had 31.86% of the sample units, Davaar had 25.66% and Sweet Valley with 42.48%. Information collected through questionnaires includes household characteristics, crops grown, output realized, and cost of production, amount of labour used, and access to extension services. Table 1 shows the summary statistics of household characteristics for A1 and A2 plot holders.

Table 1: Household Characteristics

Characteristic of Household head		A1 farmers	A2 farmers
Age	Average	56.12	58.3
Gender	Male	71%	73%
	Female	29%	27%
Marital Status	Married	62%	57%
	Divorced	5%	8%
	Widowed	28%	32%
	Single	5%	3%
Education Level	Primary	26%	33%
	Secondary	54%	49%
	Tertiary	10%	8%
	No school	10%	10%

Source: own calculations

As can be seen from table 1, the household demographics of A1 and A2 farmers are rather comparable, with most of the differences less than 5 percentage points. According to the Zimbabwe education system, level of education is usually classified into 3 categories which are primary (up to 7 years), Secondary/high school (up to 13years) and Tertiary education (colleges and universities). Previous studies often show that education is a significant variable in explaining technical efficiency—more educated farmers are expected to be able to utilize inputs into more efficiently. In our sample, the majority of the household heads received secondary education. Only 10% and 8% of A1 and A2 households' heads obtained tertiary education.

Table 2 shows different crops grown by A1 and A2 farmers in Mazowe South district and total land allocated to each crop. Seven different types of crops are grown in the region, including maize, soya bean, cotton, sorghum, groundnuts, sugar beans and sunflower.

Table 2: Crops Grown in Mazowe South District

Crop grown	% of area put under the crop	% of farmers growing the crop
Maize	47%	100%
Soya beans	24%	73%
Cotton	10%	35%
Sorghum	5%	27%
Groundnuts	5%	44%
Sugar beans	3%	22%
Sunflower	2%	26%
Fallow land	4%	21%

Source: own survey

As can be seen, maize is the primary crop in the region, grown by all farmers surveyed and in almost half of the land area. Next, we examine the summary statistics of maize production in our sample, as shown in table 3.

Table 3: Summary statistics of maize production

Location	Statistic	Area(ha)	Yield (kgs)	Costs(US$)/ha
A1 farmers	Mean	2.925	2073.885	253.588
N=113	Standard Dev	1.453	654.173	75.118
	Minimum	1	800	63
	Maximum	6.5	3800	480
	Mean	5.495	2149.81	373.0825
A2 farmers	Standard Dev	2.72	591.662	189.5
N=63	Minimum	1.8	982.1	140
	Maximum	11.5	3705	1164

Source: own calculations

On average, the yields of maize produced by A1 and A2 farmers are 2073.9 kg/hectare and 2149.81 kg/hectare, respectively. It appears that farmers in our data were performing significantly better as compared to un-resettled farmers who usually produce at a national average of 1200kgs per hectare as noted by Rukuni et. al (2006).

4. Estimation Results

In this section, we summarize our estimation results of the parametric Stochastic Frontier model and data envelopment analysis, as well as factors affecting the technical efficiency of maize production among smallholder farmers in Zimbabwe.

4.1 Results from Parametric Stochastic Frontier Model

The un-restricted linearized Cobb-Douglas production function as in equation (2) is estimated using Ordinary Least Squares method. The regression results are presented in table 4.

Table 4: Results of Regression Model in Equation (2)

A1 model DEPENDENT VARIABLE ouput			**A2 model** DEPENDENT VARIABLE ouput		
Independent Variables	Coefficient	Std. Error	Independent Variables	Coefficient	Std. Error
Constant	4.06151***	0.55	Constant	5.2698***	0.759
land	0.35706***	0.124	land	0.6950***	0.161
labour	0.59912***	0.107	labour	0.4045***	0.149
capital	0.15370*	0.088	capital	0.0603	0.080
R-squared: 0.8038			R-squared: 0.8312		
Adjusted R-squared: 0.7984			Adjusted R-squared: 0.8227		
F(3,109): 148.8***			F(3,59): 96.87***		

Note: 1% '***' 5% '**' 10% '*'

Estimation results suggest that at least 80% variations in maize output can be explained by variations in land, labour and capital for both A1 and A2 farms. The elasticities of output with respect to land is 0.35 for A1 farmers and 0.69 for A2 farmers, *ceteris paribus*. It appears that A2 famers perform better than their A1 counterparts in utilizing land. However, the elasticity of output with respect to labour is higher for A1 farmers, reaching 0.599 as compared to 0.4045 for A2 farmers. A percentage change in capital used for production would on average result in 0.154% increase in maize output for A1 farmers and 0.06% for A2 farmers, respectively. Land and labour are significant in explaining changes in output for both types of smallholder, while capital is only significant for A1 farmers. Additionally, we find that maize production for both types of farms to exhibit an increasing returns to scale, as the total returns to scale in the Cobb-Douglas function (sum of the b_i coefficients) are both greater than 1.

Given the specified Cobb-Douglas stochastic frontier regression results, maximum likelihood (MLE) procedure is used to estimate the technical efficiency score as defined in equation (3). The predicted results of technical efficiency are shown in table 5 for both A1 and A2 farmers.

Table 5: Summary of Technical Efficiency as Calculated Using Equation (3)

Statistics	A1 farmers	A2 farmers
Minimum	0.1523	0.3490
Mean	0.3675	0.386
Maximum	0.6278	0.4967

Source: own calculations

The minimum and maximum values of technical efficiency are 0.1523 and 0.6278 for A1 farmers, respectively. For A2 farmers, these numbers are 0.349 and 0.4967, respectively. The average technical efficiency appears to be rather similar, 0.3675 for A1 and 0.386 for A2. The wide range of technical efficiency for A1 farmers indicates that there are much heterogeneity in their production performances. About 60% of the A1 farmers have technical efficiency scores between 0.3 and 0.5, while the score for A2 farmers are all between 30 and 50%. Results from the parametric Stochastic Frontier model suggest that A1 and A2 households in Zimbabwe are not efficiently utilizing their available agricultural resources in maize production. The low efficiency score found for the majority of the farms suggests that significant cost reduction or output growth can be attained if land, capital, or labor are used more efficiently.

Fig 1 below illustrates the Kernel density estimates of technical efficiency of individual A1 smallholder maize producers.

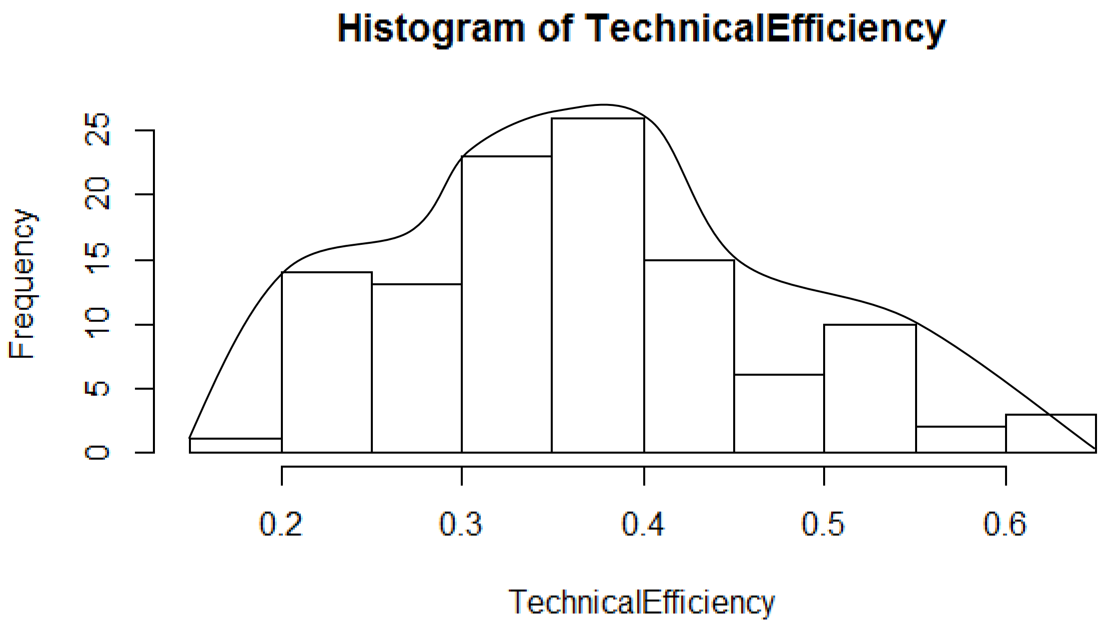

Fig 1: Kernel density estimates of the technical efficiency for A1 farmers

4.2 Results from DEA model

Given the DEA model with specified linear programming model in equation (4)-(8), we run the optimization model and find technical efficiency scores higher as compared to those obtained using the SF approach. We consider both constant returns to scale (CRS) and variable returns to scale (VRS) assumptions. A summary of results are shown below in table 6.

Table 6: Average Technical Efficiency from DEA model

Description	Constant Returns to Scale DEA (CRSTE)	Variable Returns to Scale DEA (VRSTE)	Scale Efficiency = CRSTE/VRSTE
A1 farmers	0.625 *(0.303)*	0.771*(0.347)*	0.813*(0.306)*
A2 farmers	0.631*(0.278)*	0.808*(0.372)*	0.791*(0.306)*

Source: Own calculations: note minimum values in parenthesis

The DEA model is a comparative analysis to peers with efficient score of 1 on the frontier. The minimum VRS values of technical efficiency are 0.771 and 0.808 for A1 and A2 farms, respectively. For constant returns to scale the mean efficiency for A1 and A2 are 0.625 and 0.631, respectively. The minimum values shown (in parenthesis) indicate that most of the farmers are not technically efficient in maize production when comparing with the best peer. These numbers appear to be much higher than those obtained from the parametric Stochastic Frontier model. However, this should not be surprising the DEA approach attributes any deviation from the production frontier as technical inefficiency while in the Stochastic Frontier model the deviation is decomposed into technical inefficiency and random errors that cannot be controlled by individual farmers. Regardless, the numbers appear to be low compared to agricultural production in other regions. For instance, Poudel et al. (2015) find mean technical efficiency score of coffee production in Nepal to be 0.89 and 0.83 in organic and non-organic farms, respectively.

4.3 Determinants of Technical Efficiency

We next investigate the factors affecting technical efficiency of maize production among smallholder farmers in Zimbabwe using equation (9). The efficiency score for each farmer is derived from the parametric Stochastic Frontier model in section 4.1. The estimation results are shown in table 7, in which the dependent variable U_k (the inefficiency score), is regressed against farmer characteristics.

Table 6: Determinants of Technical Inefficiency

Independent Variable	Coefficient	Std. Error
Constant	-0.6495**	0.2543
Male	-0.1575**	0.0763
Widowed	-0.0512	0.1528
Divorced	-0.0739	0.1703
Married	0.0307	0.1234
Age of head	0.0007	0.0033
Primary	0.0008	0.0859
Secondary	-0.121	0.1001
Tertiary	-0.3734***	0.1196
Household size	-0.0013	0.0109
Extension Services	-0.147***	0.0559
Soya bean	-0.0237	0.0571
Cotton	0.0595	0.0551
Groundnut	-0.037	0.0577
Sugar bean	-0.0675	0.0623
Sunflower	-0.0023	0.0577
Sorghum	-0.0256	0.0566
R-squared	0.3253	
Adjusted R-squared	0.1961	

Note: 1% '***' 5% '**' 10% '*'

Gender of the household head is significant in explaining variations in inefficiency at 5% level of significance. The efficiency score of a male-headed household is on average 0.157 higher compared to a female-headed household in maize production, holding all other factors constant. Level of education is also found to be statistically significant. A tertiary-educated household head on average produce maize on average has an efficiency score 0.37 higher than a farmer who did not receive any education. However, it appears that obtaining primary or secondary education do not significantly improve production efficiency. Access to extension services is significant at 1%, and access to extension work can increase the efficiency score by 0.147 compared to a farmer without access to extension services. Age of head, household size and marital status were shown to play little role in explaining the technical efficiency of maize production among smallholder farmers.

5. Conclusions

In this study, we examined the technical efficiency of maize production among smallholder famers in Zimbabwe. Specifically, we seek to answer: i) Are smallholder farmers efficiently allocating their land, labour and capital resources when producing maize? ii) If maize production is found to be inefficient, then what determines variations in efficiency levels?

Using a sample of 176 farms consisting of 113 A1 and 63 A2 households from the Mazowe South district ward 14 (Long Croft, Sweet Valley, and Davaar areas), we find that there is a significant potential for farmers in Zimbabwe to improve their efficiency either by reducing input use and producing same output or increasing output at their same level of operation. The average technical efficiency is found to be 36.75% (38.6%) with the Stochastic Frontier Analysis, and 62.5% (63.1%) and 0.77.1% (0.808%) with the Data Envelopment Analysis for constant returns to scale and various returns to scale for A1 (A2) farmers, respectively. Land and labour are found to be significant in explaining variations in maize output. Gender of the household head, attaining tertiary education, and access to extension services has been found to be significant in explaining farmer efficiency levels.

A2 farmers appears to be more technically efficient as compared to their A1 counterparts when producing maize, but the differences are small. A1 and A2 plots in the study area are not separated but are mixed together and the only difference between the two types is on land size. They face almost similar issues, compete for the same labour, and these families moved from similar communal areas. Therefore the finding that they exhibit almost similar performance in maize production should not come at a surprise.

If the government of Zimbabwe allows complete agricultural land markets, farmers would be more efficient as the land marketing system promotes competitive domestic food and agricultural marketing systems through leasing in and out of land. Increasing the extension services to smallholder farmers' would improve production efficiency. There is also a great need to encourage farmers to acquire tertiary education and as well encourage male headed households to put more land under maize production as they are efficient compared to female headed households.

References

Abu, O & Kirsten, F. (2009). Profit efficiency of small and medium-scale maize milling enterprises in South Africa. Development South Africa 26(3), 353-368.

Aigner D.J., Lovell C.A.K. and P. Schmidt (1977), Formulation and estimation of stochastic frontier function models », Journal of econometrics, 6(1): 21 – 37

Asogwa Benjamin C., Joseph C. Umeh and Simon T. Penda. (2011) Analysis of Economic Efficiency of Nigerian Small Scale Farmers: A Parametric Frontier Approach. Kamla-Raj 2011 J Economics, 2(2): 89-98.

Bangwayo-Skeete, P. F., Bezabih, M., & Zikhali, P. (2010). Are Zimbabwe's Fast Track Land Reform Farms more Technically Efficient than Communal Farms? Quarterly Journal of International Agriculture, 49(4), 319.

Bhatt Mohammad Sultan and Bhat Showkat Ahmad. (2014). Technical Efficiency and Farm Size Productivity—Micro Level Evidence From Jammu & Kashmir. International Journal of Food and Agricultural Economics ISSN 2147-8988 Vol. 2 No. 4, pp. 27-49

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. European journal of operational research, 2(6), 429-444.

Cliffe, L., Alexander, J., Cousins, B., & Gaidzanwa, R. (Eds.). (2014). Outcomes of Post-2000 Fast Track Land Reform in Zimbabwe. Routledge.

Farrel, J. M. (1957). The Measurement of Productive Efficiency. Journal of Royal Statistic, 120 (3): 253-290.

Food and Agriculture Organization (FAO): GIEWS country briefs: Zimbabwe. http://www.fao.org/giews/countrybrief/country.jsp?code=ZWE, accessed Jan 11, 2016

Francesco Porcelli, (2009). Measurement of Technical Efficiency. A brief survey on parametric and non-parametric techniques.

Greene, W. H. (1997). Frontier production functions. In Pesaran, M. H. and Shmidt, P., editors, Handbook of Applied Econometrics, vol II: Microeconometrics. Blackwell Publishers Ltd.

Lovell, C. K. (1993). Production frontiers and productive efficiency. In Fried, A. O., Lovell, A. K., and Schmidt, S. S., editors, The Measurement of Productive Efficiency, chapter 1, pages 3 – 67. Oxford University Press.

Meeusen W. and J. Van den Broeck (1977), Efficiency estimation from Cobb-Douglas production functions with composed error », International economic review, 18(2): 435 – 444

Mugabe Douglas, Nyasha Chipunza, Norman Mupaso, Vincent Tinashe Munyati & Fungai Violet Makarudze. (2014). Estimation of Optimal Land Use Allocation among Small Holder (A1) Farmer Households in Zimbabwe. A Case Study of Long Croft Farm, in Mazowe District. Journal of Agricultural Science; Vol. 6, No. 2.

Mushunje, A., Belete, A., & Fraser, G. (2003). Technical efficiency of resettlement farmers of Zimbabwe. In 41st Annual Conference of the Agricultural Economic Association of South Africa (AEASA), Pretoria, South Africa.

Nyekanyeka Ted, (2011). Analysis of profitability and efficiency of improved and local smallholder dairy production: A case of Lilongwe milk Shed area.

Obi, A. (2011). Performance of smallholder agriculture under limited mechanization and the fast track land reform program in Zimbabwe.

Oguntade, A., Fatunmbi, T., & Okafor, C. (2012). Effects of Farmers' Field School on the Technical Efficiency of Cocoa Farmers in Nigeria. *Journal of Biology and Life Science*, *4*(1).

Pallotti A and Tornimbeni Corrado. (2015). State, land and Democracy in Southern Africa. Contemporary African Politics. University of Bologna, Italy. Ashgate.

Poudel, K. L., Johnson, T. G., Yamamoto, N., Gautam, S., & Mishra, B. (2015). Comparing technical efficiency of organic and conventional coffee farms in rural hill region of Nepal using data envelopment analysis (DEA) approach. Organic Agriculture, 5(4), 263-275.

Resti, A. (2000). Efficiency measurement for multi-product industries: A comparison of classic and recent techniques based on simulated data. European Journal of

Rukuni, M., and Eicher, C. K. (2006). Zimbabwe's Agricultural Revolution Revisited. UZ publications. Harare, Zimbabwe.

Scoones, I., Marongwe, N., Mavedzenge, B., Murimbarimba, F. Mahenehene, J. and Sukume, C. (2011). Zimbabwe's Land Reform: A summary of findings. IDS: Brighton

Zikhali, P. (2008). Fast track land reform, tenure security, and investments in Zimbabwe. Göteborg University, Sweden.