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## Article

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## GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

# Analysis of factors affecting technical efficiency of A1 smallholder maize farmers under command agriculture scheme in Zimbabwe: The case of Chegutu and Zvimba Districts

Norman T. Muzeza<sup>1</sup>, Amon Taruvinga<sup>1</sup> and Peter Mukarumbwa<sup>2\*</sup>

**Abstract:** In an effort to address the decline in maize productivity, the government of Zimbabwe in 2016/17 endorsed a special program for input support named command agriculture scheme (CAS). Against this background, the study questioned the beneficiaries' technical efficiency and factors that influence farmers to gravitate towards the frontier using Chegutu and Zvimba districts of Zimbabwe as case studies. The study used a cross-sectional survey of 240 households randomly selected through a three-stage multiple-sampling procedure. The single-stage modelling stochastic frontier approach was applied to assess technical efficiency of A1 smallholder command agriculture maize farmers. The study revealed that A1 smallholder command agriculture maize farmers in Chegutu and Zvimba districts were technically efficient at 85% and 94%, respectively. The major determinants of technical efficiency were basal fertilizer, labour, area allocated to maize production and topdressing fertilizer which all indicated a positive relationship. The main determinants of technical inefficiency were age, maize farming experience, level of education, marital status, occupation status and other sources of income. Results further revealed that farmers from Chegutu district had increasing returns to scale (1.43) while farmers from Zvimba district had decreasing returns to scale (0.54). The study therefore argues that despite the observed high technical efficiencies,

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Norman T. Muzeza is a final year MSc. student with the University of Fort Hare, in the Department of Agricultural Economics and Extension. His research interests are in rural development, women entrepreneurship, food value chains, livelihoods and women entrepreneurship.

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Peter Mukarumbwa holds a PhD in Agricultural Economics from the University of Fort. Hare, South Africa. He is a full-time Senior Lecturer in the Department of Agricultural Economics and Extension at the National University of Lesotho. Currently, he teaches several courses in agricultural economics and has engaged in the supervision of research projects for both undergraduate and postgraduate students in the same department. He has over a decade of researching and working with marginalized communities in different countries from Southern Africa which include, Lesotho, Zimbabwe, South Africa, Botswana and Namibia. He has also participated in a number of conferences which include experts from the region and beyond to address key issues such as climate change, food security, global financial crisis and innovative farming methods for the rural poor in Africa.

Chegutu farmers could bridge their 15% gap between the observed output and the frontier output by focusing more on input usage with increasing returns to scale while Zvimba farmers could bridge their 6% gap by focusing more on socio-economic drivers of technical inefficiency given their decreasing returns to scale.

**Subjects:** development studies; politics & development; sustainable development; development policy; economics and development

**Keywords:** technical efficiency; stochastic frontier; productivity; maize; smallholder farmers

## 1. Introduction

Maize production is an essential component of food security and livelihoods among smallholder farming communities in Zimbabwe. Being the staple food of many people in the country, maize is the most important commodity in terms of food security. Most smallholder farmers grow maize primarily for subsistence purposes (Mazvimavi et al., 2012). Since the implementation of the fast track land reform programme (FTLRP) in 2000, there have been radical changes in the structure of the agricultural sector in Zimbabwe. An estimated 70% of the Zimbabwe population now lives in small-scale farming areas (Mano, 2006). This has significant implications for food security, given the critical role of the smallholder sector in producing the staple maize crop. Crop failures and inefficiencies in smallholder maize production have had negative serious repercussions on the country's food security situation.

Consequences of the FTLRP were clearly felt in the agricultural environment of Zimbabwe, forcing production numbers to dramatically change in a negative sense (Scoones et al., 2012). Unavailability and inaccessibility of inputs influenced the harvest and production of farmers, resulting in a decline of maize production (Mutonodzod-Davies, 2010). Hence, production inefficiency amongst resettled smallholder farmers caused a drastic decline in agricultural productivity since the launch of the FTLRP widening the supply and demand gap of food especially the staple maize leading to massive food insecurity in the country.

Due to this continual reduction in maize production, during the 2016/2017 agricultural season, the government of Zimbabwe endorsed a program named Command Agriculture Scheme (Mazwi et al., 2017). Command Agriculture Scheme (CAS) is a special program for import substitution introduced to promote food self-security, through domestic agricultural production (Ministry of Agriculture Mechanization and Irrigation Development, 2016). The scheme was meant to mobilize sustainable and affordable funding for the agricultural sector. Farmers would benefit from agricultural inputs in an endeavor to boost production of strategic crops and restore sanity in the provision of adequate food and nutrition to rural populace (Makuwerere Dube, 2020). Moreover, the scheme had also an import substitution-led industrialization concept deliberately meant to empower local producers of cereal crops and creating employment for thousands of people in the sector (Kuhudzayi & Mattos, 2018). Against this background, the study investigated the drivers of technical efficiency among A1 smallholder maize farmers participating in the CAS.

### 1.1. Problem statement

In recent years, maize production in Zimbabwe has steadily declined (Mango et al., 2015). Data from the Food and Agriculture Organization (FAO, 2016), show that Zimbabwe was a net exporter of maize prior to 2001, and a net importer after 2001. It is estimated that between 650 and 700 thousand tons, or about one-third of the total domestic maize demand, was imported for the 2015/16 marketing year (FAO, 2016). This exceptionally poor performance of the maize subsector in Zimbabwe, relative to comparable regional countries with similar natural environments, implies the existence of problems in internal mechanisms working against progress and diminishing Zimbabwe's maize productivity. Agricultural production decline in the country contributed to

food insecurity and intensified poverty (Chimhowu et al., 2010; Nyawo, 2012). This is a concern given the significance of agricultural output to the viability of numerous industries and sectors that rely on agriculture for raw materials and market (Zikhali, 2008).

This study utilizes survey data obtained from two districts of Zimbabwe to analyse factors affecting technical efficiency of resettled A1 smallholder maize farmers under the command agriculture scheme (CAS). Currently, there is dearth of information available on the command agriculture scheme and its contribution to agricultural productivity in Zimbabwe, especially under A1 smallholder farmers. The paper made an important policy contribution towards designing of both public and private policies on key entry points that can be tapped into, so as to improve smallholder maize farmers' productivity under the command agriculture scheme.

## 2. Technical efficiency

Technical efficiency is a component of economic efficiency and reflects the ability of a farmer to maximize output from a given level of inputs (e.g., output-orientation). Several studies have evaluated the efficiency of resource use in agricultural production. Tracing theoretical developments in measuring technical efficiency to early works by (Färe & Knox, 1978), there has been increasing literature on technical efficiency of smallholder agricultural production in Zimbabwe. However, there are limited studies related to state-led contract or government contract farming such as command agriculture scheme. Reviewing global literature, remarkable works focusing on smallholder farmers' technical efficiency under government programs, government contracts and private contract farming do exist (Mango et al., 2015; Masuku et al., 2015; Mishra et al., 2018; Siziba et al., 2017). The average technical efficiency of smallholder farmers reported in these studies ranges between 0.45 and 0.90. This shows that smallholder farmers have low and highly variable levels of technical efficiency, especially in developing countries.

Literature on technical efficiency in African agriculture is emerging. Globally, however, there is a wide body of empirical research on the economic efficiency of farmers in both developed and developing countries. While empirical literature on technical efficiency of farmers under different input support programs is vast in developed countries, Asian economies and a few African countries, there are limited studies in Zimbabwe that mainly focus on farm level technical efficiency of farmers participating under command agriculture scheme. It is against this background, that this study applied the single-stage modelling stochastic frontier approach to assess technical efficiency of A1 smallholder maize farmers under the command agriculture scheme in Zimbabwe.

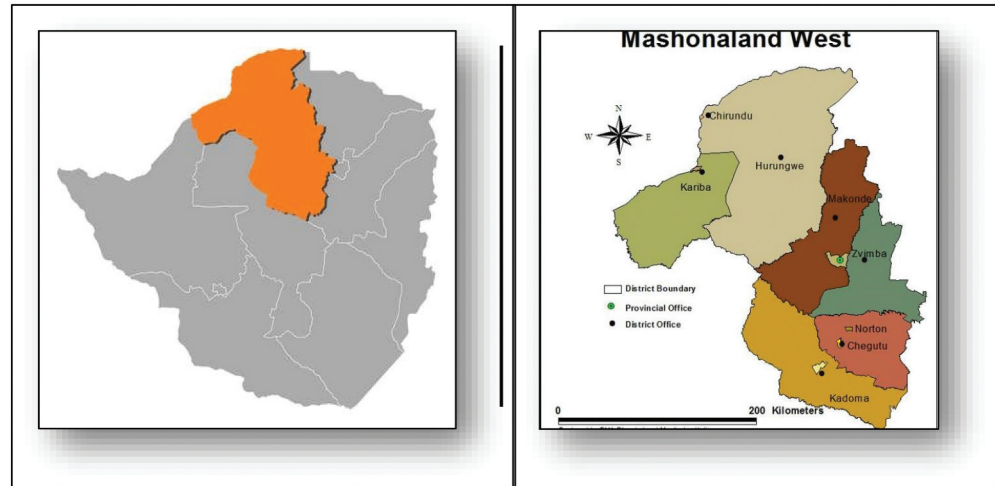
## 3. Material and methods

### 3.1. Study area

The study was conducted in Chegutu and Zvimba Districts which are both located in Mashonaland West Province of Zimbabwe. Figure 1 shows location of these study areas. Mashonaland West Province has traditionally been the biggest producer of maize in the country (Odunze et al., 2015). However, the majority of people who dwell in Mashonaland West Province are classified as poor, and the main factor that accounts for the widespread poverty is lack of formal employment or poor salaries. As such, use of technical inputs is very low due to the fact that the majority of the farmers cannot afford them (Sachikonye, 2005). In addition, erratic rainfall patterns experienced in Zimbabwe have contributed to poor agricultural maize yields, and lead to poverty and food insecurity.

Chegutu district is located in natural region II, in the middle of the northern part of the country. Rainfall ranges from 750 to 1 000 mm/year (Mazwi et al., 2017). It is fairly reliable, falling from November to March/April. Temperatures for Chegutu District range from 23°C in June to 31.3°C in October (Climate\_Data, 2019). Following agrarian and land reform program initiated in 1999/2000, a large proportion of farms were subdivided into smaller units and allocated to new farmers under the A1 and A2 farming system. Chegutu district is a highly maize producing area, with production mainly done by A1 smallholder and A2 large-scale farmers (Katema et al., 2017). Smallholder

**Figure 1. Location of study areas in Mashonaland West Province, Source: (Google maps).**



farmers constitute a larger population in the district. They produce maize mainly for consumption and sell surplus to local markets or the Grain Marketing Board (GMB).

Zvimba district is under natural region IIa, with the highest diversified agricultural activities. In Zvimba district, the monthly maximum temperatures range between 21.8°C in June to 29.8°C in October (Climate\_Data, 2019). This implies that maize performs well between September and April as it is a summer crop that requires a mean summer temperature of more than 23°C. Rainfall conditions are highly favorable for maize production, as it normally receives about 828 mm of rain per year, with most rainfall precipitating during mid-summer from October to March (Climate\_Data, 2019).

### 3.2. Sampling procedure and sample size

The study adopted a cross-sectional survey research design through employing face-to-face interviews. Multiple sampling methods were used in different stages with purposive, cluster and random sampling components being utilised to draw a representative sample of A1 smallholder maize farmers in Mashonaland West Province. In the first stage, purposive sampling was used to select Chegutu and Zvimba Districts out of the six districts in Mashonaland West Province. The two districts were selected because they possess climatic conditions of natural region IIa and IIb respectively, and these regions are very favorable for maize production (Mkodzongi, 2013). In the second stage clustered sampling procedure was applied followed by random selection in the third stage. A list of command agriculture scheme participants was collected from the Grain Marketing Board (GMB) for the two districts. There are 830 A1 smallholder maize farmers under CAS from Chegutu and Zvimba districts (Ministry of Agriculture Mechanization Irrigation and Development, 2017). For sample size determination, the (Yamane, 1967) formula for determining the sample size was used as illustrated below:

$$n = \frac{N}{(1 + Ne)} = \frac{830}{(1 + (830(0.05)^2))} = 270$$

Where: n = sample size, N = population size, and e = Margin of error (MoE), e = 0.05.

Thus far, 270 questionnaires were administered during data collection targeting 270 respondents (135 from each district). All of them responded giving a participation rate of 100%. During data analysis 240 questionnaires were used while 30 were invalid. Thus far, 89% of the target respondents were considered after discarding spoiled questionnaires to give a sample size of 240 respondents.

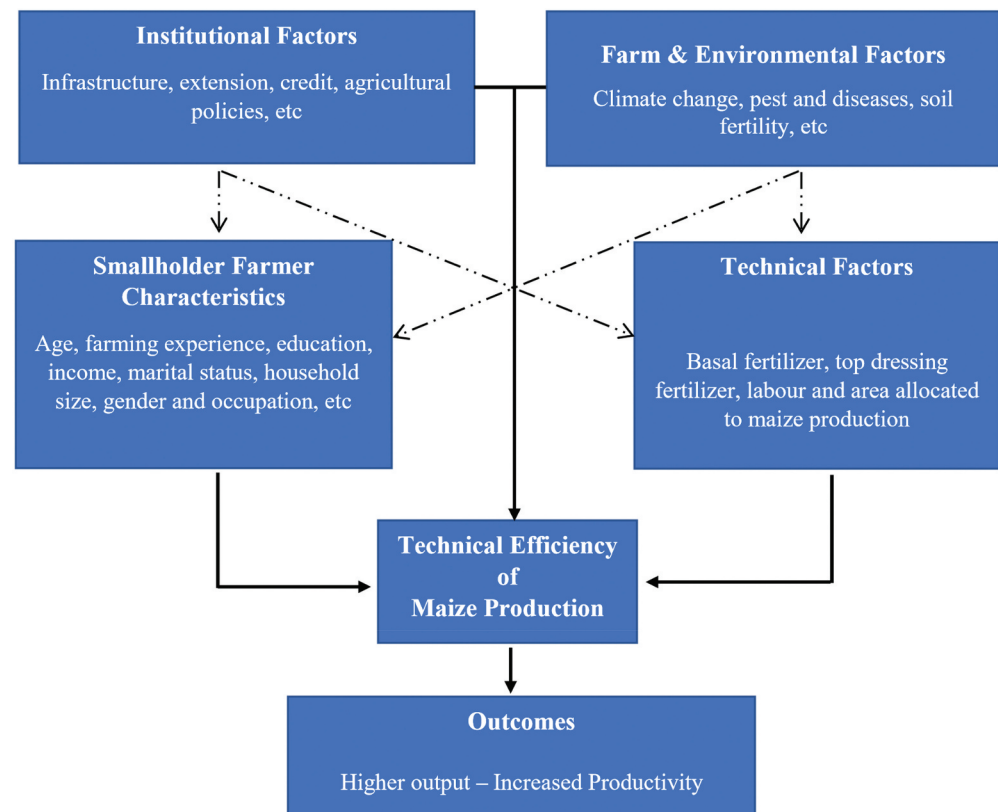


### 3.3. Conceptual framework

The conceptual framework in Figure 2 demonstrates interrelationship of key variables that promote technical efficiency in maize production. Evidence exists that provision of input to farmers is one of the best ways of improving their agricultural activity and restore livelihoods to acceptable levels (Kato & Greeley, 2016). This is against a background where a production process is expected to transform inputs into outputs. For maize production, the following inputs are required; fertilizer, land seed and labour. Farmer managerial practices, socio-economic attributes and farm characteristics are also equally important in the transformation of inputs to outputs (Kassa, 2017). Thus far, efficiency of production is directly and indirectly affected by several institutional and socio-economic factors (Chimai, 2011; Kassa, 2017; Magreta, 2011). Figure 2 therefore shows the interaction of a host of variables capable of impacting on the level of technical efficiency among smallholder maize farmers.

Institutional (infrastructure, extension, credit and agricultural policies), farm and environmental (climate change, pest and diseases, soil fertility) factors may have direct or indirect influence of technical efficiency. Their indirect influence is manifested through technical and farmer level characteristics as illustrated in Figure 2. A host of these factors therefore influence the degree to which individual farmers gravitated towards the frontier. Environmental factors like climate change, pests and diseases have been reported to affect efficiency in maize production (Shrestha et al., 2014). Institutional factors also influence maize production efficiency depending on whether they are supportive of non-supportive (Kassa, 2017; Magreta, 2011). At farmer level socio-economic attributes will also influence how individual farmers combine technical inputs into outputs (Addai et al., 2014; Kassa, 2017). Technical factors like fertilizer usage and labour will also influence technical efficiency of maize production given the generic poor soils in most rural farming areas of Zimbabwe.

**Figure 2. Conceptual framework, source: Modified from (Kassa, 2017).**



The outcome of the conceptual framework presents the expected net effect of the interaction of endogenous (farm and farmer characteristics) and exogenous (environmental and institutional) variables (Kassa, 2017). Depending on how these variables exist at individual level, outcome effects of technical efficiency can be negative or positive (Chimai, 2011). A positive outcome is premised for this study assuming these variables provide a favorable environment for smallholder maize farmers.

### 3.4. Data analysis

The study adopted methods of analysis similar to the work of (Bempomaa & Acquah, 2014). Using various analytical techniques which are outlined below, data was analysed using a combination of Stata 15 (IC version) and Microsoft EXCEL.

### 3.5. Parametric stochastic frontier model (SF)

The stochastic production function model proposed independently by (Aigner et al., 1977) was used for estimating technical efficiency in this study. For cross-sectional data, the model can be expressed as illustrated in equation (1) following (Bempomaa & Acquah, 2014) as indicated:

$$Y_i = f(X_i; \beta) \exp(\varepsilon_i) = f(X_i; \beta) \exp(V_i - U_i), i = 1, 2, \dots, N \quad (1)$$

Where  $Y_i$  represents the output of the  $i^{\text{th}}$ ,  $X_i$  is vector containing the logarithms of inputs,  $\beta$  is a vector of unknown parameters to be estimated, and  $\varepsilon_i$  denotes the composed error term consisting of two independent elements  $V_i$  and  $U_i$  such that  $\varepsilon_i = V_i - U_i$ .  $V_i$  presents the stochastic noise and other factors beyond the farmers' control;  $U_i$  denotes the inefficiency error term which is non-negative. This allows all observations to be below the stochastic production frontier. The two sided error term  $V_i$  is identically and independently distributed with mean zero and variance  $\sigma_v^2$ . Furthermore,  $V_i$  and  $U_i$  are distributed independently of each other and of the independent variables. Following from equation (1), technical efficiency can then be specified as:

$$T_i = f(X_i; \beta) \exp(V_i - U_i) / f(X_i; \beta) \exp(V_i) = \exp\{-u_i\} \quad (2)$$

With reference to equation (2), the  $T_i$  (technical efficiency) is the ratio of the observed output to the frontier output. Technical efficiency takes a value between zero and one. If  $u_i = 0$ , then the production firm is 100% efficient; if  $u_i > 0$ , then there is some inefficiency. From a series of studies, authors have explored the implications of a variety of distributional assumption and estimation of efficiency (Balogun et al., 2017; Mango et al., 2015). Generally, it is required to assume a distribution of  $u_i$  from (Balogun et al., 2017):

Half-normal distribution:  $u_i \sim N^+(0, \sigma_u)$

Exponential distribution:  $\text{EXP}(\lambda)$

Truncated-normal distribution:  $u_i \sim N^+(u_i, \sigma_u)$

Gamma distribution:  $\gamma \sim (m, \sigma_u)$

The choice of distribution of  $u_i$  influences quite strongly a level of TE and less rankings of inputs. Under a weak assumption, it is usually possible and appropriate to estimate models using the method of least squares (Bempomaa & Acquah, 2014). Slightly stronger distributional assumption allows estimating unknown parameters using maximum likelihood (Coelli et al., 2005).

### 3.6. Specification of the empirical model

The Cobb-Douglas production function was adopted to estimate the stochastic frontier production function. The Cobb Douglas functional form was selected because it is flexible, self-dual and its



returns to scale are easily interpreted (Bravo-Ureta & Evenson, 1994). The empirical model of the stochastic production frontier is specified as illustrated in equation (3) below:

$$\log Y_i = \beta_0 + \sum_{i=1}^4 \beta_i \log X_i + e_i; e_i = v_i - u_i \quad (3)$$

Where  $Y_i$  is the output of maize (tonnes) produced by  $i^{\text{th}}$  A1 farmer in 2018/2019 season,  $X_i$  is a vector of four input variables including labour, basal fertiliser, top dressing fertiliser, and area of land allocated to maize production, as indicated in Table 1.  $\beta_i$  denotes the unknown parameters to be estimated;  $v_i$  denotes random shocks;  $u_i$  is the one-sided non-negative error representing inefficiency in production.

### 3.7. Estimating factors affecting technical efficiency

The single-stage approach was adopted for this study. From (Bempomaa & Acquah, 2014), the approach involves a concurrent estimation where inefficiency effects are expressed as an explicit function of explanatory variables. The study examined factors that affect farmers' production performance, as illustrated in equation (4) following Mango et al. (2015):

$$U_i = \alpha_0 + \sum_{i=1}^8 \alpha_i Z_i \quad (4)$$

Where;  $\alpha_0 \dots \alpha_i$  are parameters to be estimated,  $Z_i$  is a vector of farmer and household socio-economic characteristics including: marital status, gender, age, educational level of household head, household size, other sources of income and occupation status, as explained in Table 1 below:

### 3.8. Estimating the level of productivity

According to (Onumah et al., 2010), the estimated parameters  $\beta_1, \beta_2 \dots \beta_4$  are output elasticities of corresponding inputs in the Cobb-Douglas stochastic frontier production function. However, elasticities of output based on different inputs are functions of the level of inputs employed in the Cobb-Douglas stochastic production function. Moreover, when the output and input variables have been normalized by their respective sample means, the first-order coefficient can be interpreted as elasticities of output in relation to the different inputs. That means elasticities of inputs from the Cobb Douglas production function are equal to coefficients. Based on the farm's output elasticities, it would be known whether the farm exhibits constant returns to scale, decreasing returns to scale or increasing returns to scale and implication to the farm. The summation of all output elasticities gives the returns to scale (RTS) as illustrated by equation (5) below:

$$RTS = \sum_{i=1}^4 e_i \quad (5)$$

## 4. Results and discussion

### 4.1. Summary statistics

Table 2 presents a summary of demographics and socio-economic characteristics for sampled A1 smallholder maize farmers under Command Agriculture Scheme from Chegutu and Zvimba districts. On average, across all districts, the distribution of gender revealed more males than females, 56% and 55% for Chegutu and Zvimba Districts, respectively.

Marital status findings indicated that the majority of household heads were married in Chegutu district (47.50%) and Zvimba district (48.33%). The survey identified that, among the participants, the largest group of A1 farm owners had attended secondary education across all the two districts 46% and 50% for Chegutu and Zvimba district respectively. In terms of occupation status, the largest group was represented with full-time farmers in Chegutu district (37.50%) and Zvimba district (35.83%). The dominant age group among sampled A1 smallholder maize farmers ranged from 41 to 50 years (30%) in all districts, with 30% in Chegutu district and 34.2% in Zvimba district,

**Table 1. Description of the variables in the model**

Variable	Variable name	Type of variable	Description of variable
<b>Y<sub>i</sub></b>	Output	Continuous	Total yield/ hectare of maize harvested cultivated under command agriculture scheme (2018/2019 season) expressed in kilogram
<b>X<sub>1</sub></b>	Basal fertiliser	Continuous	Total quantity of basal fertiliser per hectare applied to maize expressed in kilograms
<b>X<sub>2</sub></b>	Top dressing	Continuous	Total quantity of top dressing applied in kilograms
<b>X<sub>3</sub></b>	Labour	Continuous	Total labour utilised in maize production expressed in man-day equivalents (expressed in adult equivalent days per ha, as the sum of family labour and hired labour)
<b>X<sub>4</sub></b>	Area	Continuous	Land area allocated to maize under Command Agriculture Scheme in the 2018/2019 season expressed in hectares
<b>Socio-economic factors</b>			
<b>Z<sub>1</sub></b>	Age	Continuous	Age of famer in number of years
<b>Z<sub>2</sub></b>	Maize farming experience	Continuous	Experience of the farmer in number of years
<b>Z<sub>3</sub></b>	Education level	Dummy variable	Educational level of farmer, a dummy variable which takes the value of (1 = tertiary and secondary education, and 0 = otherwise)
<b>Z<sub>4</sub></b>	Source of income	Dummy variable	Source of income, dummy variable (1 = Salary and wages, 0 = otherwise)
<b>Z<sub>5</sub></b>	Marital status	Dummy variable	Marital status, dummy variable (1 = married, 0 = otherwise)
<b>Z<sub>6</sub></b>	Household size	Continuous	Number of family members in the household
<b>Z<sub>7</sub></b>	Gender	Dummy variable	Gender of household head (1 = female, 0 = male)
<b>Z<sub>8</sub></b>	Occupation	Dummy variable	Employment of the household head (1 = formal employment, 0 = otherwise)

**Table 2. Summary of descriptive statistics**

Sampled households			Chegutu district		Zvimba district		Total
Variable	Class		Number of respondents		Number of responde		Variable
			Frequency	Percentage			Frequency
Gender	Male		67	55.83	66	55	133
	Female		53	44.17	54	45	107
Total			120	100	120	100	240
Marital status	Married		57	47.50	58	48.33	115
	Widowed		14	11.67	23	19.17	37
	Divorced		8	6.67	7	5.83	15
	Single		41	34.17	32	26.67	73
Total			120	100	120	100	240
Education status	Pre-school		3	2.5	1	0.83	4
	Primary education (grade1-7)		23	19.17	29	24.17	52
	Secondary education (Form1-6)		55	45.83	60	50	115
	Tertiary education		39	32.50	30	25	69
Total			120	100	120	100	240
Occupation status	Full-time farmer		45	37.50	43	35.83	88
	Part-time farmer		37	30.83	42	35	72
	Pensioner		10	8.33	8	6.67	18
	Formally employed		28	23.33	27	22.5	55
Total			120	100	120	100	240
Other source of Income	Salaries Wages	and	28	23.33	26	21.67	54
	Retirement pension		11	9.17	13	10.83	24
	Remittances		43	35.83	40	33.33	83
	None		38	31.67	41	34.17	79
Total			120	100	120	100	240
Age	20-30		14	11.67	8	6.7	22
	31-40		31	25.83	40	33.3	71
	41-50		36	30	41	34.2	75
	51-60		33	27.5	25	20.83	58
	61-70		6	5	5	4.2	11
	71-80				1	0.83	1
Total			120	100	120	100	240
Maize producing experience	1-5		9	7.5	20	16.67	29
	6-10		35	29.17	40	33.33	75
	11-15		67	55.83	49	40.83	116
	16-20		8	6.67	11	9.17	19
	21-25		1	0.83			1
Total			120	100	120	100	240

(Continued)

**Table 2. (Continued)**

Sampled households			Chegutu district		Zvimba district		Total
Variable	Class		Number of respondents		Number of responde		Variable
			Frequency	Percentage			Frequency
Household size	1-5		71	59.17	67	55.83	138
	6-10		44	36.67	53	44.17	97
	11-15		5	4.17			5
<b>Total</b>			120	100	120	100	240
	Chegutu district				Zvimba district		
	Min		Max	Ave	Min	Max	Ave
Age		23	69	44.42	24	73	46.48
Household size		1	13	5.36	2	10	4.96

Maize 2 2 1 1 1 2 19 9.49 producing experience

respectively. Finally, distribution in maize production experience in all two districts was as follows: the largest group ranged from 11 to 15 years in Chegutu district (55.83%) and Zvimba district (40.83%) respectively. No much variation existed between the demographics of the respondents from the study sites.

#### 4.2. Level of technical efficiency for Chegutu and Zvimba farmers

Table 3 represents technical efficiency scores for A1 smallholder maize farmers under CAS from Chegutu and Zvimba districts.

From Table 3, both districts indicated that the largest group of farmers falls under level of technical efficiency, ranging from 91% to 100%. Zvimba district had a larger number of farmers (52.5%) under this category, compared to Chegutu district (48%). The level of technical efficiency for the second largest group of farmers ranged from 81%—90% in both districts. The results further reveal that most farmers scored above 50% level of technical efficiency, although there were minor farmers struggling to achieve an average technical efficiency of 50%. In Zvimba district, the minimum level of technical efficiency was 29%, while in Chegutu district, the minimum level of technical efficiency was 27%.

Zvimba district indicated a high mean level of technical efficiency (94%) than Chegutu district (85%). Zvimba district has better rainfall patterns compared to Chegutu district, and this might explain the observed variation in output. The results, therefore, suggest that in both districts, since the technical efficiency of the farmers is below 100% (1), all sampled maize farmers produced below the frontier. The wide variation range in the technical efficiency scores among farmers may be that farmers' combination of inputs yielded different output level *ceteris paribus* (Bempomaa & Acquah, 2014). With respect to Chegutu, a mean technical efficiency level of 85% implies that maize farmers could bridge the gap between their observed output and frontier output by 15%, while Zvimba farmers will only require 6% to bridge the gap.

#### 4.3. Factors that influence technical efficiency

Estimates of the normal/truncated-normal stochastic frontier production function model for Chegutu and Zvimba districts are presented in Table 3. The model for Chegutu district estimated 120 observations, with  $\text{Prob} > \chi^2 = 0.000$ , indicating that all estimated parameters are significant for assessing the level of technical efficiency. The model for Zvimba district also estimated 120 observations, with  $\text{Prob} > \chi^2 = 0.000$ , indicating that all estimated parameters are significant for assessing the level of

technical efficiency. It is evident from the measures of variance, namely, sigma squared ( $\sigma^2_{ui}$ ) and Lambda, which are statistically significant, that the choice of normal/truncated-normal distribution for the error  $u_i$  was the best choice, as it ensured the robustness of the models.

#### 4.4. Maximum likelihood estimates

From Table 4, Maximum Likelihood (ML) estimates of a Cobb-Douglas production function for maize production by A1 smallholder command agriculture maize farmers in Chegutu and Zvimba districts indicates that all parameters have a positive relationship. In Chegutu district, the following parameters, basal fertilizer, area of land cultivated and labour showed positive signs and were statistically significant, implying that maize production is positively influenced by these variables. In Zvimba district, the following parameters: basal fertilizer, top dressing fertilizer and area indicated positive signs and were also statistically significant, meaning that maize production is positively influenced by these variables.

#### 4.5. Amount of basal fertiliser applied

From Table 4, the amount of basal fertiliser applied by sampled A1 smallholder maize farmers from Chegutu is significant at 5% level, with a p-value of 0.012. With respect to Zvimba, the amount of basal fertiliser applied is significant at 1% level, with a p-value of 0.002. The positive relationship indicates that increase in the usage of basal fertiliser increased the maize yield of A1 smallholder farmers. In Chegutu, a 1% increase in the amount of basal fertiliser resulted to 0.51% increase in the maize yield per hectare, while a 1% increase in the amount of basal fertiliser for Zvimba led to a 0.16% increase in the maize yield per hectare *ceteris paribus*. This is not surprising since the use of basal fertiliser (which comprises high levels of potassium and phosphorus) tends to promote initial maize growth (root establishment, stem elongation, photosynthesis, respiration and energy storage and transfer) so that it can be fully established and enhance productivity. Similar findings have been observed by (Abdulai et al., 2013), arguing that basal fertiliser improves output in crop production.

#### 4.6. Top dressing fertiliser

The amount of top-dressing fertiliser applied by sampled A1 smallholder maize farmers for Zvimba was significant at 5% level, with a p-value of 0.021. The positive relationship indicates that an increase in the usage of top-dressing fertiliser increases the maize yield of A1 smallholder farmers from Zvimba district. Results reveal that a 1% increase in the amount of top-dressing fertiliser leads to a 0.10% increase in the maize yield per hectare *ceteris paribus*. Top dressing fertilizer mainly contains nitrogen critical for photosynthesis, protein production, grain filling and stem elongation that enhances productivity.

#### 4.7. Labour

This variable is significant at 1% level of significance with p-value of 0.000 for Chegutu A1 smallholder maize farmers. The positive coefficient sign indicates a positive relationship between labour and maize yield. The results reveal that a 1% increase in labour (person-days), *ceteris paribus*, would lead to 0.43% increase in maize yield. Since smallholder farmers are known to be resource-constrained while maize production is labour-intensive, an increase in labour will positively enhance several labour-based maize production activities such as land preparation, planting, weeding, fertilizer and chemical application, as well as harvesting. Similar findings were also observed by several studies (Belete, 2020; Kassa, 2017).

#### 4.8. Area of land allocated for maize production

Area of land allocated for maize was significant at 1% level of significance (for both study areas), with a p-value of 0.000 suggesting that an increase in the area of land allocated for maize production will positively increase maize yield. The results indicate that a 1% increase in the area of land allocated to maize production lead to a 0.49% increase in maize yields for Chegutu A1 smallholder farmers, while a 1% increase in the area allocated to maize production will lead to a 0.27% increase in maize yields for Zvimba A1 smallholder farmers *ceteris paribus*. Large land

**Table 3. Frequency table for technical efficiency**

Technical efficiency (%)	Chegutu district		Zvimba district	
	Frequency	Percentage	Frequency	Percentage
30<	1	0.8%	1	0.8%
31–50	3	2.5%	9	7.5%
51–60	2	1.6%	5	4.2%
61–70	3	2.5%	5	4.2%
71–80	18	15%	7	5.8%
81–90	35	29%	30	25%
91–100	58	48%	63	52.5%
<b>Total</b>	<b>120</b>	<b>100%</b>	<b>120</b>	<b>100%</b>
<b>Mean TE</b>	<b>85%</b>		<b>94%</b>	
<b>Minimum TE</b>	<b>27%</b>		<b>29%</b>	
<b>Maximum TE</b>	<b>97%</b>		<b>99%</b>	

sizes allocated to maize will enhance conservation farming activities like crop rotation to promote productivity, compared to small land sizes normally dominated by mono-cropping of maize. These results are consistent with several studies (Belete, 2020; Siziba et al., 2017; Weldegebriel, 2015).

#### 4.9. Determinants of technical inefficiency

Inefficiency parameters shown in Table 4 relate to farm-specific characteristics and socioeconomic position for A1 smallholder farmers from Chegutu and Zvimba districts under the command agriculture scheme. The parameters include gender of the household head, household size, age of the household head, farming experience, education level of the household head, marital status, occupation status and other sources of income. Among the eight variables estimated, only two were statistically significant in Chegutu district, while six were statistically significant in Zvimba district.

##### 4.10. Age of household head

Age was statistically significant at a 10% level of significance, with a positive coefficient for Chegutu A1 smallholder farmers. The positive coefficient sign indicates that a 1% increase in age leads to a 0.016% increase to technical inefficiency. This means young A1 smallholder farmers are more technically efficient in the production of maize compared to older farmers in Chegutu district. This can be a result of education level and easy access to maize production information, new technologies and precision online farming applications, which have migrated online mainly packaged in the English language. Since the majority of young farmers are educated and have easy access to internet than their older counterparts, the observed association may be explained by easy access of online maize husbandry information, precision online farming, technologies and varieties by young farmers. These findings are consistent with results obtained by (Deme et al., 2015). On the contrary, several previous studies have noted an increase in efficiency with age attributed to farming experience (Belete, 2020; Bempomaa & Acquah, 2014).

##### 4.11. Maize farming experience

Maize farming experience was significant at 5% level, with a p-value of 0.024 for Chegutu A1 farmers and significant at a 1% level with a p-value of 0.003 for Zvimba A1 smallholder maize farmers. The negative coefficient sign in both cases indicates that an increase in maize farming experience decreases technical inefficiency. The results for Chegutu A1 smallholder maize farmers reveal that a 1% increase in maize farming experience leads to a 0.06% reduction in technical inefficiency and a 0.075% decrease in technical inefficiency for Zvimba A1 smallholder maize farmers *ceteris paribus*. Farming experience positively contributes to efficient use of production resources because of previous experiences gained.



**Table 4. Results for stochastic frontier normal /truncated-normal model**

Variables	Chegututu District		Zvimba District	
	<b>Log likelihood = 29.7771</b> <b>Number of observations = 120</b> <b>Wald Chi<sup>2</sup>(4) = 166.77</b> <b>Prob &gt; Chi<sup>2</sup> = 0.0000</b>		<b>Log likelihood = 51.0131</b> <b>Number of observations = 120</b> <b>Wald Chi<sup>2</sup>(4) = 146.77</b> <b>Prob &gt; Chi<sup>2</sup> = 0.0000</b>	
	<b>Coefficient P &gt;  z </b>		<b>Coefficient P &gt;  z </b>	
<b>Efficiency</b>				
In Basal Fertilizer	.5050014	0.012**	.1601673	0.002***
In Topdressing (Nitrogen) fertilizer	.0078996	0.958	.1015932	0.021**
In Labour	.433437	0.000***	.0018922	0.945
In Area	.4862647	0.000***	.2732007	0.000***
Constant	−3.166892	0.000	−.2027457	0.297
<b>Inefficiency</b>				
Age	.0160226	0.073*	−.0056353	0.543
Maize farming experience	−.0636937	0.024**	−.0651351	0.003***
Education	−.4618088	0.100	−.7382213	0.008***
Other source of Income	.1257705	0.148	.2850171	0.021**
Marital status	−.2394319	0.229	−.3986791	0.040**
Household size	−.0568161	0.260	.0394243	0.384
Gender	−.6177181	0.173	.3998544	0.004***
Occupation	−.0880149	0.777	.3865227	0.030**
Cons	.5893647	0.100	.2587617	0.224
<b>Diagnostics</b>				
Sigma_u	.2935304	0.001	.0487456	0.000
Sigma_v	.1451364	0.000	.1565852	0.000
lambda	2.022445	0.000	.3113042	0.000
<b>Mean technical efficiency = 84%</b>			<b>Mean technical efficiency = 94%</b>	

\*, \*\* and \*\*\* means significance at 10%, 5% and 1%, respectively

#### 4.12. Education

Education was significant at a 1% level with a p-value of 0.008 for Zvimba A1 smallholder maize farmers. The negative coefficient sign indicates that an increase in education decreases technical inefficiency. The results reveal that a 1% increase in education leads to a 0,74% decrease in technical inefficiency *ceteris paribus*. From literature, smallholder farmers who attained some level of education are expected to be more efficient, presumably due to their ability to acquire technical knowledge, which makes them closer to the frontier (Kitila & Alemu, 2014).

#### 4.13. Other sources of income

Other sources of income was significant at a 5% level with a p-value of 0.021 for Zvimba A1 smallholder maize farmers. The positive coefficient sign indicates that an increase in other sources of income increases technical inefficiency. The results reveal that a 1% increase in other sources of income leads to a 0,29% increase in technical inefficiency *ceteris paribus*. Respondents argued that access to other sources of income would reduce farmers' time and attention on maize farming activities negatively, thus affecting productivity. Earned income from other sources was also not

large enough to pay for labour to manage maize production. Similar comparable observations were noted by several studies highlighting that off-farm income received might not be used for financing farming activities, and farmers might have spent much of their time working off the farm and failing to manage their maize farms properly, thus off-farm income opportunities may reduce farm resources and the farmers' farming efforts (Alene & Hassan, 2003; Baruwā & Oke, 2012; Deme et al., 2015; Obwona, 2006).

#### **4.14. Marital status**

Marital status was significant at a 5% level with a p-value of 0.040 for Zvimba A1 smallholder maize farmers. The negative coefficient sign indicates that change of the household head from being single (0) to married (1) among A1 smallholder maize farmers decreases technical inefficiency. The results reveal that a 1% change of the household head from being single to married leads to a 0,399% decrease in technical inefficiency *ceteris paribus*. Married household heads have labour benefits critical for maize productivity that is labour intensive (land preparation, planting weeding, chemical spraying and harvesting). The observed association may be explained by extra labour benefits associated with married households.

#### **4.15. Gender**

Gender was significant at 1% level with a p-value of 0.004 for Zvimba A1 smallholder maize farmers. The positive coefficient sign indicates that a change from a male (0) to female (1) headed household among A1 smallholder maize farmers increases technical inefficiency, implying that male farmers are relatively more efficient in maize production compared to female farmers. The results reveal that a 1% change from a male to female-headed household leads to a 0,399% increase in technical inefficiency *ceteris paribus*. Considering that planting, weeding, harvesting and other crop management operations are labour-intensive and more suited to males, this result is not surprising. Female farmers also have relatively less access to productive resources. The result could also be explained by the imbalance in resource access by gender. These findings are consistent with previous comparable studies highlighting that in some communities, agricultural activities are deemed a male's work, meaning males allocate the majority of their times for outdoor activities where agriculture is the paramount (Belete, 2020).

#### **4.16. Occupation status**

Occupation status was significant at a 5% level with a p-value of 0.030 for Zvimba A1 smallholder maize farmers. The positive coefficient sign indicates that an increase in occupation status increases technical inefficiency. The results reveal that a 1% increase in occupation status leads to a 0,39% increase in technical inefficiency *ceteris paribus*. A farmer with a formal occupation (outside farming) will have reduced farming time and attention on maize farming activities, thereby negatively affecting productivity, while income received from formal occupation outside farming might not be used to finance farming activities, as suggested by previous literature (Deme et al., 2015; Goodwin et al., 2004; McNally, 2002).

#### **4.17. Estimating the productivity level**

Table 5 indicates productivity level of A1 smallholder maize farmers under CAS in Chegutu and Zvimba districts. The productivity is observed from the production elasticities and returns to scale.

From Table 5, all inputs are inelastic, with a positive relationship with output from both districts. Input elasticities are deemed inelastic if a 1% increase in the input leads to a less than 1% increase in output (Bempomaa & Acquah, 2014). Under Chegutu district, basal fertiliser had the largest elasticity coefficient of 0.505, followed by area allocated to maize with an elasticity coefficient of 0.486. Under Zvimba district, the area allocated to maize had the largest elasticity coefficient of 0.273, followed by basal fertiliser with an elasticity coefficient of 0.160. Since all input elasticities are inelastic and have a positive relationship with output, an effort to increase their usage in Zvimba district will not significantly increase output *ceteris paribus*. With respect to Chegutu district, in as much as all input elasticities are inelastic, an effort to increase their

usage (basal fertiliser, labour and area) will increase output, albeit less in proportion to the amount of input used as follows: a 1% increase in basal fertiliser usage will increase output by 0.505%, while a 1% increase in labour will increase output by 0.433%. Lastly, a 1% increase in area allocated to maize production will increase output by 0.486%.

In terms of returns to scale, the production function of farmers from Chegutu district exhibited increasing returns to scale (1.4326), whilst farmers from Zvimba district exhibited decreasing returns to scale (0.5369). Thus far, a proportionate 1% increase in all inputs for Chegutu A1 smallholder maize farmers under CAS will increase output by 1.43% *ceteris paribus*, since they are operating at an irrational stage of production with a mean technical efficiency of 85%. To improve their scale of production efficiently, the following inputs may be targeted: basal fertiliser, labour and area allocated to maize production *ceteris paribus*. With reference to Zvimba A1 smallholder maize farmers under CAS, a proportionate 1% increase in all inputs will increase output by 0.54% *ceteris paribus*, since their mean technical efficiency is close to 100% (94%). Thus far, to improve their scale of production efficiently, the following inputs may be targeted: basal fertiliser, top dressing fertiliser and area allocated to maize production *ceteris paribus*.

#### 4.18. Insights drawn from the analysis

The following understandings can be drawn from the results presented in this chapter. Firstly, results highlight relatively high technical efficiency of A1 smallholder maize farmers under the CAS from both districts (Chegutu = 85%; Zvimba = 94%). Despite the relatively higher mean technical efficiency, results reveal that all sampled A1 smallholder maize farmers under command agriculture scheme produced below the frontier, with a wide variation range in their technical efficiency scores suggesting that farmers' combination of inputs yielded different output levels that can be attributed to different socio-economic attributes of farmers and location.

Secondly, farmers could bridge the gap between their observed output and the frontier output by targeting input usage and several socio-economic factors, as detailed below. Chegutu farmers with a lower mean technical efficiency score (85%) have a better option of targeting input usage than socio-economic factors. A proportionate increase in all inputs for Chegutu farmers will more than double output. In addition, they could increase the scale of production efficiently by employing more inputs, specifically basal fertiliser, labour and area allocated, to maize production to expand output. Socio-economic factors like age and experience in maize farming are also other options that may be targeted to improve output.

Thirdly, Zvimba farmers with a higher technical efficiency score (94%) have a better option of bridging the gap between their observed output and frontier output by targeting socio-economic factors such as farming experience, education, other sources of income, gender, marital status and occupation status. This may be supported by employing more inputs, specifically basal fertiliser, top dressing fertiliser and area allocated to expand output although this route may not yield much in terms of output improvement.

**Table 5. Elasticity of production and returns to scale (RTS)**

Variable	Chegutu district	Zvimba district
	Elasticity	Elasticity
In Basal Fertiliser	.5050014	.1601673
In Topdressing (Nitrogen) fertiliser	.0078996	.1015932
In Labour	.433437	.0018922
In Area	.4862647	.2732007
<b>RTS</b>	<b>1.4326027</b>	<b>0.5368534</b>

## 5. Conclusions

The study concluded that, A1 smallholder maize farmers under command agriculture scheme from Chegutu and Zvimba districts of Zimbabwe exhibited high level of technical efficiency (85% and 94%, respectively), suggesting good usage of inputs by the majority of these farmers. However, despite good usage of inputs by the majority of sampled farmers, all were producing below the frontier, with wide variation ranges in their technical efficiency scores. Thus far, farmers' combination of inputs yielded different output levels, with room for improvement to bridge the gap between the observed output and the frontier output. Output can be increased by increasing the usage of the following inputs: basal fertilizer, labour and area allocated for maize production for Chegutu farmers. Zvimba farmers will need to increase usage of basal fertilizer, top dressing fertilizer and area allocated for maize production to boost output. With reference to socio-economic factors, the following factors (age, other source of income, sex and occupation) increase technical inefficiency, while an increase/change in the following factors (maize farming experience, education and marital status) reduces technical inefficiency. Lastly, the production function of farmers from Chegutu district exhibited increasing returns to scale, whilst the production function of farmers from Zvimba district exhibited decreasing returns to scale.

Overall, the study argues that despite high levels of technical efficiency from the study areas, Chegutu farmers could bridge their 15% gap between their observed output and frontier output by focusing more on input usage with increasing returns to scale (1.43%). Zvimba farmers could bridge their 6% gap between their observed output and frontier output by focusing more on socioeconomic drivers of technical inefficiency, given the decreasing returns to scale of their inputs (0.54%).

### 5.1. Policy recommendations

To improve maize output for A1 smallholder maize farmers under the command agriculture scheme from Chegutu district:

- (1) The study recommends a proportionate increase in the usage of the following inputs: basal fertilizer, labour and area allocated to maize production. These inputs have a statistically significant positive influence on technical efficiency. The elasticity coefficients are close to one (although inelastic) and the return to scale is above 1% (1.43%), thus suggesting an increasing return to scale.
- (2) This may be supported by strategic targeting of the following socio-economic factors: age and experience in maize farming. Targeted training of less experienced maize farmers, informal education, digital literacy training and easy access of maize farming information among older farmers will reduce technical inefficiency.

To improve maize output A1 smallholder maize farmers under the command agriculture scheme from Zvimba district:

- (1) The study recommends strategic targeting of the following socio-economic factors maize farming experience, other sources of income, education, marital status, gender and occupation. Customized informal education training on maize production targeting less experienced and uneducated farmers will reduce technical inefficiency and improve output. Addressing sex differential barriers will reduce technical inefficiency among female headed households capable of improving output. Allocating more labour to maize production (as manifested through marital status) among single headed households will also trigger output. For households with other occupations and sources of income outside maize farming, enough allocation of their time and resources to maize production may reduce technical inefficiency and promote output.
- (2) The above may be supported by a deliberate increase in the usage of the following inputs: basal fertilizer, topdressing fertilizer and area allocated to maize production. These inputs have a statistically significant positive influence on technical efficiency.

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