

ASSESSMENT OF PROFIT EFFICIENCY OF SMALLHOLDER MAIZE FARMERS IN LIMPOPO PROVINCE, SOUTH AFRICA: A STOCHASTIC FRONTIER APPROACH

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Abstract. The primary goal of this study is to evaluate the profit efficiency and identify the factors influencing profit inefficiency among small-holder maize farmers in the Limpopo province of South Africa. The research employed a stochastic profit frontier approach and collected primary data by administering a semi-structured questionnaire to 307 smallholder farmers, who were selected using a stratified random sampling method across all five districts in the study area. The results revealed that profit efficiency ranged from 0 to 0.90, with an average of 0.612. This suggests that by improving technical and allocative efficiencies, the typical maize farmer could potentially increase their profits by 38.8%. This presents opportunities for farmers to elevate their agricultural earnings, leading to a reduction in poverty. This progress could significantly impact many farmers, particularly since maize farming is their primary source of income. As a result, increasing investment in extension education through producer organisations is recommended in order to enhance agricultural productivity and improve agricultural marketing by effectively utilising marketing information.

Keywords: profit efficiency, determinants, smallholder maize farmers, stochastic profit cost function, Limpopo province, South Africa

INTRODUCTION

Maize, scientifically known as *Zea Mays* L., originates from the Tehuacán Valley of Mexico and was spread across the Americas around 2500 B.C. (Mangelsdorf and Reeves, 1938). The earliest record of maize in Africa dates back to 1549, when a Portuguese pilot discovered established maize fields in the Cape Verde Islands (McCann, 2001). According to Kempton (1931) and McCann (2001), maize was first introduced in South Africa in 1655 and has since become one of the primary food crops.

Maize is considered a vital crop in Africa and is undeniably a primary source of income for many families (Tewodros, 2001). Maize serves as both a raw material for various industrial products and a source of sustenance for both humans and animals (James, 2003). The author also notes that maize cultivation and production levels make it the second most important cereal in the world after wheat.

Maize's economic significance is expanding globally, both as a staple food and for commercial purposes, prompting it to become the primary crop for many farmers (Manyong et al., 2000). Maize serves as the main food source for around 900 million impoverished individuals and one-third of all undernourished children. In developing nations, the demand for maize was estimated to have risen by 72% from 1997 to 2020, totalling

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213 million metric tonnes for that period (James, 2003). The International Maize and Wheat Centre (CIMMYT) and the International Institute of Tropical Agriculture (IITA) (2010) have predicted that, by 2025, maize will be the highest-producing crop worldwide.

The pivotal contribution of smallholder farmers to the advancement of agriculture in Africa generates substantial economic interest and, consequently, augments additional income at the farm or farmer level, assuming all other factors remain constant (Ezihe et al., 2017). As articulated by Sinyolo et al. (2014), the domains of smallholder agriculture and rural development are instrumental in alleviating poverty and mitigating unemployment. In other terms, the enhancement of the roles of farmers has prompted the government to implement a range of initiatives aimed at fostering the development of smallholder agriculture. This process encompassed the deployment of extension officers within the wards to facilitate the execution of governmental programmes, alongside land reform initiatives that led to the establishment of new legislation regarding water rights (Ofiah, 2015; AgriSA, 2017).

At this point, it has become imperative to delineate the concept of agriculture within the South African framework. Agriculture, as articulated by Von Loeper et al. (2016), is comprised of two distinct categories of farmers: the subsistence farmers located in the former homeland regions and the large-scale commercial farmers, predominantly of white descent. This characterization, however, stands in stark contrast to the agricultural landscape observed in numerous other nations worldwide, where a diverse spectrum of farm sizes exists, encompassing the very small or subsistence farmers to the exceedingly large agribusiness entities (Ibeawuchi et al., 2015). Consequently, there exists a robust consensus regarding the proposition that agriculture represents a substantial investment opportunity and is indispensable for developmental progress throughout the South African region (Alliance for a Green Revolution in Africa, 2017).

In general, the level of maize production fluctuated between 2005 and 2009, but stabilized between 2002 and 2004 (DAFF, 2018). In 2009, South Africa transitioned from being a net importer of maize in 2007 to a net exporter. Due to its growing significance, the maize industry is currently a significant source of foreign exchange earnings through the export of maize and its derivatives (Macauley, 2015). According to AgriSA (2017), maize is the most significant source of carbohydrates in

southern Africa and the largest field crop grown locally. Among the land used for crop agriculture in South Africa, it is important to remember that the land used for maize plantings ranked highest, followed by wheat and, to a lesser degree, sugarcane and sunflowers (SACCG, 2017).

The efficiency of technical processes (TE) reflects how effectively a specific set of resources is utilised to generate a particular level of output. To achieve the highest output level with a given input, a farmer must be technically efficient (Elsamma and George, 2002). In Limpopo province, in South Africa, numerous smallholder farmers primarily grow maize for both sustenance and income generation. However, Seini et al. (2011) found that agricultural performance in Africa has been extremely disappointing over the past decades. Given the crucial role of agriculture, especially in rural areas, this poor performance poses a significant threat that needs to be addressed. Therefore, this research aims to assess the profitability of the crop among smallholder maize growers in the study area.

MATERIALS AND METHODS

Study area

The study was conducted in Limpopo (Fig. 1), one of South Africa's provinces (Fig. 2), which has a population of 5,854,000 (1 million inhabitants) and is located in the northern part of the country bordered by Zimbabwe, Botswana, and Mozambique. It has an area of 125,754 km² and is divided into five districts: Capricorn, Vhembe, Sekhukhune, Mopani, and Waterberg.

The survey included all the districts. The area is famous for wildlife and Bushveld, and it includes a portion of the Kruger National Park. Polokwane, formerly known as Pietersburg, is the capital city of the Limpopo province.

Sampling technique and sample size of the study

The Department of Agriculture in Limpopo provided a database containing the details of the smallholder maize farmers in the specified area, as of November 2020. For this study, 307 smallholder maize growers were selected to take part, using a stratified random sampling method encompassing all five districts in the province. The sample size was determined by the Krejcie and Morgan formula as follows:

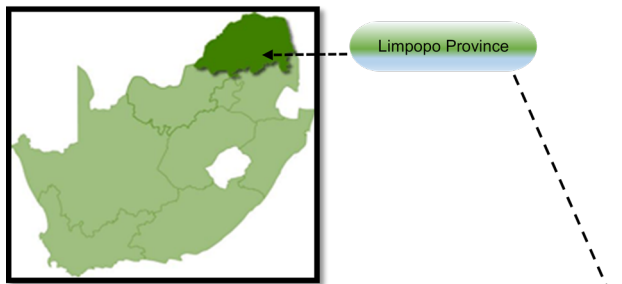


Fig. 1. Map of South Africa showing Limpopo Province
Source: Google Maps.



Fig. 2. Map of Limpopo province
Source: Municipalities of South Africa, 2024.

The formula is constructed as follows:

$$S = \frac{X^2 NP(1 - P)}{d^2(N - 1) + X^2 P(1 - P)}$$

Where:

- S – required sample size
- X^2 – table value of chi-square for 1 degree of freedom at a desired confidence level (3.841)
- N – population size
- P – population proportion (assumed to be 0.5, since this would provide the maximum sample size)
- D – the degree of accuracy expressed as a proportion (0.05)

$$S = \frac{(3.841)(1518)(0.5)(1 - 0.5)}{(0.0025)(1518 - 1) + (3.841)(0.5)(1 - 0.5)}$$

$$S = \frac{1457.7}{4.7528}$$

$$S = 307$$

The sample size was then stratified according to the 5 districts/geographical with different numbers of

farmers, hence the different sample sizes presented in Table 1. A simple random sampling was employed to select each district's respective samples. The Department of Agriculture classifies all farmers as smallholder farmers, therefore, having some common characteristics.

Table 1. Population and sample size of the study

District	Targeted smallholder farmers (N)	Sample size
Capricorn	107	22
Mopani	379	77
Sekhukhune	378	76
Vhembe	510	103
Waterberg	144	29
TOTAL	1518	307

Source: author's computation, 2022.

Data collection

Primary data was collected using a semi-structured questionnaire with questions aligned with the study's objective. The questionnaire included both open-ended and closed questions. It was divided into four sections, namely, demographic and socio-economic characteristics, production, marketing, and challenges facing the farmers. The primary data utilised in the analysis was obtained through face-to-face interviews with 307 smallholder maize farmers in the research area. The interview tool was validated by two agricultural economists at the University of South Africa and piloted on 15 farmers not included in the main survey.

Data analysis

Primary data was collected from smallholder maize farmers, and it was carefully coded, processed, arranged, and analysed. STATA 17, a software for statistics and data, was used to conduct the data analysis.

Model specification

The study utilised the stochastic profit frontier approach, as outlined by Ojo et al. (2009) and Oguniyi (2008), who employed the Battese and Coelli (1995) model to formulate a profit function that is presumed to conform to the stochastic frontier concept. The profit

frontier model commences by examining a stochastic profit function with a multiplicative disturbance term as depicted in equation (1).

$$\pi = f(p_i, Z_{ik}\beta_i)e(E_i) \quad (1)$$

The normalised profit, represented by π , is calculated by subtracting the variable cost from the gross revenue and then dividing the result by the price of the output. The normalised price of variable inputs used by the farm, denoted by p_i , is obtained by dividing the cost of these inputs by the price of the output. The level of the k th fixed factor on the farm is denoted as Z_{ik} . The vectors of parameters are represented by β_i . An error term, denoted by e_i , is utilised. Additionally, the stochastic disturbance term, E_i , consists of two independent elements, V_i and U_i .

$$E_i = V_i + U_i \quad (2)$$

where

V_i follows a $NID(0, \delta^2)$ distribution, while U_i represents profit inefficiency in a one-sided disturbance form and is independent of V_i .

The stochastic profit function model is applicable for analysing cross-sectional data. It estimates both the individual profit efficiency of the respondents and the factors influencing the profit efficiency at the same time. By combining equations (1) and (2), as outlined in equation (3), the farm's frontier is determined.

$$\pi = f(P_i, Z_{ik}, \beta) e^{(U+V)} \quad (3)$$

The ratio of predicted actual profit to the predicted maximum profit for a maize farmer defines the profit efficiency of an individual farmer, as shown in equation (4).

Profit efficiency ($E\pi$)

$$\frac{\pi}{\pi^{\max}} = \exp \frac{\exp[\pi(p,z)] \exp(\ln V) \exp(\ln \mu) \theta}{\exp[\pi(p,z,0)] \exp(\ln V) \theta} \quad (4)$$

Where π = predicted actual profit and $\pi^{\max}$ = predicted maximum profit

The frontier profit function can be estimated using the maximum likelihood technique, considering the density function of U_i and V_i . The expected value of π falls within the range of 0 to 1. When U_i equals 0, indicating that it lies on the frontier, the farmer can achieve the maximum potential profit based on the price and fixed

factors. However, if U_i is greater than 0, the farm operates inefficiently, leading to reduced profit. To estimate all parameters simultaneously, the stochastic frontier function with behavioural inefficiency components, as described by Coelli et al. (2005) and Ojo et al. (2009), was utilised in a one-step maximum likelihood estimation procedure. The specific Cobb-Douglas functional form for the maize producers in the study area was explicitly specified in equation (5).

$$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_n \ln X_n + \varepsilon_i \quad (5)$$

where:

$\ln$ – logarithm to base

$\ln Y$ – total profit

The explanatory variables considered are:

X_1 – fertiliser cost (R/kg)

X_2 – pesticide cost (R/litre)

X_3 – herbicide cost (R/litre)

X_4 – hybrid seed cost (R/kg)

X_5 – water cost (R/litre)

X_6 – labour cost (R/person)

X_7 – tractor cost (R/ha)

X_8 – transport cost (R/distance)

X_9 – storage cost (R/day)

X_{10} – processing cost (R/kg)

V_1 – error term not under the control of farmers

V_2 – error term under the control of farmers' profit inefficiency

β_0 – constant term

β_1 – β_{10} – parameters

The model considered various factors assumed to impact farmers' efficiency in order to determine profit efficiency. The factors influencing profit inefficiency (U_i) were modelled in the following manner:

$$U_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \varepsilon \quad (6)$$

The explanatory variables considered are:

X_1 – age (in years)

X_2 – educational level (ordinal)

X_3 – farming experience (in years)

X_4 – household size (number)

ε – error term

α_0 – constant term

δ_1 – δ_{10} – parameters

RESULTS AND DISCUSSION

Multicollinearity test

A check for multicollinearity was conducted to ensure that there is no multicollinearity among the variables chosen in the model. The suitability of variables for econometric analysis was assessed for multicollinearity using the variance inflation factor (VIF). The VIF values for the selected variables related to profit efficiency/inefficiency can be found in Table 2. For the test, the total gross profit was used as the dependent variable, while the other variables were used as independent variables. As per the findings, the index variables for both efficiency and inefficiency had an average VIF of 1.846 and 1.304, respectively. This suggests that multicollinearity was not present.

Table 2. Multicollinearity test of variables included in the profit efficiency/inefficiency analysis

Variables	Collinearity statistics	
	tolerance	VIF
Efficiency variables		
Fertiliser cost	.531	1.883
Pesticide cost	.430	2.326
Herbicide cost	.447	2.238
Hybrid seed cost	.499	2.005
Water cost	.768	1.302
Labour cost	.638	1.568
Tractor cost	.649	1.542
Transport cost	.775	1.290
Storage cost	.620	1.613
Processing cost	.372	2.691
Mean VIF		1.846
Inefficiency variables		
Age	.629	1.589
Education level	.808	1.238
Household size	.961	1.040
Farming experience	.742	1.347
Mean VIF		1.304

Source: own computation from field survey data, 2022–2023.

Parameter estimates of the stochastic cost frontier model

The variance parameters for the frontier profit function show statistical significance at a 1% level ($p < 0.001$), indicating a strong fit and confirming the accuracy of the specified error term's distributional assumptions.

The stochastic profit frontier model estimated fourteen parameters, including ten from the Cobb-Douglas frontier model and four explanatory variables believed to impact profit efficiency scores. The cost of fertiliser had a negative impact, indicating that a 1% increase in fertiliser cost would decrease profit efficiency, which is consistent with Mujuru et al. (2022) study. Labour and herbicide costs were not significant, suggesting no direct relationship with farmer profitability. However, the negative coefficient for labour cost implies that reducing hired labour expenses would improve farmer profit efficiency, in line with Jonah et al. (2020) findings. Oyewole and Oyewole (2023) also found a positive relationship between labour cost and profit efficiency. The remaining two parameters were associated with the distribution of μ_i and ν_i . Among the ten variables modelled for profit efficiency, four were statistically significant. Water, tractor, and maize processing costs were significant at the 1% level ($p < 0.001$), while transport cost was significant at the 10% level ($p < 0.10$). These findings align with Anang and Shafiwu (2022) results, indicating that tractor costs negatively impact profit efficiency among smallholder maize farmers. The coefficients of all statistically significant variables were negative, suggesting that reducing the cost of these variables would improve profit efficiency. The results indicate that a 1% increase in water, transport, and maize processing costs would lead to respective decreases in profit efficiency of 0.160, 0.126, and 3.893. It is worth noting that these factors impact in isolation on the performance of farmers, as they access them differently. For instance, some farmers do not have access to water at all, while some do have access. Moreover, in terms of the transportation to the informal market where they sell, some farmers struggle with transportation because it is expensive, while others have their own transportation.

The inefficiency model results indicated that the respondents' farming experience and level of education had negative coefficients and were statistically significant. Farming experience was significant at a 5% level ($p < 0.05$), while education was significant at a 10% level ($p < 0.10$). In a study by Dabessa et al. (2021), it was

Table 3. Maximum likelihood and profit inefficiency determinants

	Parameters	Coef.	St. Err.	<i>p</i> -value	<i>t</i> -value
Production factor					
(Constant)	β_0	−17.796	3.908	0.000	−4.55
Fertiliser cost	β_1	−.013	.623	0.839	−0.20
Pesticides cost	β_2	.053	.823	0.519	0.65
Herbicides cost	β_3	.023	.108	0.830	0.21
Hybrid seed cost	β_4	−.053	.081	0.510	−0.66
Water cost	β_5	−.160	.047	0.001	−3.42***
Labour cost	β_6	−.035	.057	0.536	−0.52
Tractor cost	β_7	−1.591	.534	0.003	−2.98***
Transport cost	β_8	−.126	.074	0.087	1.71*
Storage cost	β_9	.111	.108	0.305	1.03
Processing cost	β_{10}	−3.893	.450	0.000	8.66***
Insig2v		1.891	.084	0.000	22.63
Inefficiency variables					
(Constant)	α_0	−8.536	14.031	0.543	−0.61
Age	δ_1	.129	.191	0.501	0.67
Education level	δ_2	−.748	.678	0.070	1.68*
Farming experience	δ_3	−.019	.082	0.042	−2.68**
Household size	δ_4	−613	.506	0.226	−1.21
Sigma	2.574724				
Mean dependent var	2.367		SD dependent var		3.546
Log Likelihood	−727.72436				
Number of obs	307		Chi-square		231.385
Prob > chi2	0.000		Akaike crit. (AIC)		1489.449

*, ** and *** represents significance at 10%, 5% and 1% probability levels, respectively.

Source: own computation from field survey data, 2022–2023.

found that educational level positively impacts farmers' profitability. Conversely, a study by Amesimeku and Anang (2021) revealed that years of farming experience have a positive correlation with farmers' profit efficiency, supporting the current study's findings. These results align with Okorie et al. (2021) findings, which highlighted that educational level and years of farming experience positively influence profit efficiency to a significant degree. Therefore, it can be concluded that as these variables decrease, maize farmers' profit inefficiency

increases. Thus, maize farming experience and higher levels of education are crucial for profitability. Farmers with higher educational levels and more maize farming experience registered lower profit losses compared to those with lower education levels and less maize farming experience. Age and household size were found to be statistically insignificant, indicating that these factors did not affect farmers' profit inefficiency. This contrasts with Ngeno's (2024) study, where household size was negatively and statistically significant, suggesting that

larger households may have more labour resources and be more motivated to work, ultimately improving profit efficiency. Adnan et al. (2021) noted that age is a factor affecting profit efficiency among maize farmers, differing from the current study's findings.

Efficiency indices of the participants

Table 3 presents the profit efficiency distribution of smallholder maize farmers. The findings reveal that profit efficiency varied from 0 to 0.90, with an average of 0.612. This suggests that the average maize farmer could potentially increase their profit by 38.8%, by enhancing technical and allocative efficiencies. It indicates that there are opportunities for farmers to boost their farm incomes, ultimately contributing to alleviating poverty. This could represent a significant achievement for many farmers, given that maize farming is their primary source of income. To achieve this, government intervention is needed to assist farmers. The government can help by educating farmers about external factors like market access and climate change issues. The government can also provide training to farmers on proper maize production practices, which include the use of better fertilisers and seeds, as well as the use of agrochemicals, which will improve their output. These can significantly reduce inefficiencies in maize production and improve profitability.

Table 4. Frequency distribution of maize farmers

Efficiency class index	Frequency	Percentage
< 0.60	54	16.29
0.60–0.69	118	38.44
0.70–0.89	84	27.36
0.90–0.99	5	17.92
Mean: 0.612		
Min: 0		
Max: 0.90		

Source: own computation from field survey data, 2022–2023.

CONCLUSION

The profit efficiency of smallholder maize farmers in the study area showed a wide variation, ranging from 1% to

90%, with an average of 61%. The average level of efficiency suggests that there is potential to increase profits by enhancing technical and allocative efficiency. Education and farming experience were identified as significant factors influencing profit efficiency. These findings imply that improving the education level and providing training for farmers can significantly reduce inefficiencies in maize production. Government and private intervention is therefore needed to assist in that regard. This training may include teaching farmers about the best type of agrochemicals to use and the quantities to apply. Education on climate change issues will also benefit farmers. It is crucial to thoroughly assess the available extension services and technological packages to enhance maize production. These will ultimately help connect farmers to high-value markets, which will in turn boost profitability. Additionally, there is a need to enhance input supply policies and encourage the formation of cooperative societies among farmers in order to facilitate access to production inputs for increased production.

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