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Technical Efficiency Analysis of Small-Holder Maize Farmers in Ondo State, Nigeria.

[1]Matthew, M.D., [2] Ajibefun, I. A. and [2]Oduntan, O.

[1]Department of Agricultural Extension and Management, Federal College of Agriculture Akure, Nigeria.

[2]Department of Agricultural and Resource Economics, Federal University of Technology Akure, Nigeria.

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ABSTRACT

The study was carried out to examine the technical efficiency of small holder maize farmers in Ondo State, Nigeria. The specific objectives were to determine the efficiency level of the maize farmers in the study area, identify the determinants of maize production in the study area and identify the factors influencing farmers level of inefficiency in the study area. Multistage sampling procedure was used in selecting for the study. The Cobb Douglas functional form of the Stochastic Frontier Model (SFM) was employed to achieve the study's objectives. The Maximum Likelihood Estimate of the SFM revealed that farm size, seeds, labour, and fertilizers were significant at 1%, 5%, and 10% levels of significance, respectively. The results also indicated that the technical efficiency (TE) scores of farmers ranged from 0.152 to 0.859, with an average efficiency of 0.709. Additionally, the study revealed that age, household size, and extension contacts in the inefficiency model were significant at 1%, 5%, and 10% levels of significance. It was concluded that the farmers were not operating at maximum efficiency, with an average efficiency improvement potential of 29.1% needed for them to operate at full capacity. It was recommended amongst others that policies by relevant stakeholders should be aimed at enabling farmers to access larger plots of land and high-quality seeds through land reforms and seed subsidies.

Keywords: Technical, Efficiency, Stochastic, Frontier, Maize

INTRODUCTION

Maize, also known as corn (Zea mays), is cultivated in around 160 countries, covering nearly 150 million hectares of land. It accounts for 36% of global grain production, amounting to 782 million metric tons (Rana et al., 2018). Ranking third in global importance after wheat and rice, maize is the world's leading calorie provider, contributing 19.5% of the world's calorie intake—surpassing rice (16.5%) and wheat (15.0%) (World Atlas, 2017). Particularly crucial in poorer populations, maize is a major food crop that significantly contributes to the daily calorie intake. Its cultivation has expanded rapidly in Sub-Saharan Africa due to its high productivity and adaptability (Aminu et al., 2015). In Nigeria and other Sub-Saharan African countries, maize is a staple food, offering essential nutrients such as carbohydrates, minerals, proteins, and vitamin B (Aminu et al., 2015). As the second most cultivated crop in Nigeria, maize has a production volume of 9,180,270 tonnes, contributing approximately 1.4% to the global maize production (FAO, 2013).

In Nigeria, an estimated 45% of the maize produced is used for animal feed production, with approximately 98% of this portion being utilized by poultry farmers (PwC, 2021). Maize is composed of 71% starch, 9% protein, and 4% oil on a dry weight basis, making it a valuable source of minerals, carbohydrates, vitamin B, and protein, particularly for the population in Sub-Saharan Africa (Ebukiba, et al. (2020). In Nigeria, maize has diverse applications, including the production of corn syrup, starch, livestock feed, protein and oil, food sweeteners, beverages, fuel, sugars, corn flakes, biscuits, dextrose, and products used in baking and brewing.

Major industries that rely on maize include livestock, pharmaceuticals, food and confectionery, and beverages (Alabi, et al., 2020). Increasingly, maize is used as a feedstock for ethanol fuel production. Ethanol, when mixed with gasoline, reduces the emission of pollutants, contributing to the production of biofuels.

Nigeria's agricultural sector is primarily driven by small-scale farmers in rural areas, making the country's economic performance heavily reliant on their success (Asogwa et al., 2011). The nation is fundamentally agrarian, with over 80% of its food needs produced by peasant farmers who typically cultivate less than 2 hectares of land. Around 90% of Nigerian farmers practice subsistence farming, focusing mainly on family consumption and selling any surplus. These smallholder farmers are characterized by their low capital base, reliance on crude implements, and limited use of technology. Consequently, they often experience poverty, and their yield per hectare is very low which indicates low levels of efficiency (Ojo, 2000).

Efficiency and productivity are often used interchangeably, though they represent distinct concepts. Efficiency pertains to the effectiveness of actions, procedures, and methods in converting inputs into outputs (Lund and Hills, 2019). Rahman (2013) highlights its importance, stating that efficiency has a direct impact on productivity and economic growth. Amaechina and Eboh (2017) stress that efficiency is vital for small-scale enterprises to gauge their potential for increasing productivity, earnings, and profit, considering their current resources and available technology. Furthermore, efficiency not only enhances yield and profit for small-scale production but also guides long-term changes necessary for achieving food sustainability. Achieving efficiency involves minimizing the resources required for a given output. Njeru (2014) distinguishes between two types of efficiency: technical efficiency and allocative efficiency. Technical efficiency relates to a company's ability to maximize output given a specific resource input, while allocative efficiency concerns the effective utilization of resources in relation to their costs and production technology.

The demand for maize in Nigeria exceeds its supply, fuelled by rapid population growth, which escalates the need for agricultural products. This surge in demand has prompted farmers to intensify land cultivation in a bid to enhance agricultural productivity (Akinbile, 2008). Given the competition for maize between humans and animals, the importance of boosting productivity cannot be overstated. Higher maize productivity translates to accelerated economic growth, rural employment opportunities, resources for industrial advancement, and sustenance for the growing population. Evidence indicates the sustainability of maize production in Nigeria, emphasizing the critical role of increasing productivity, particularly among smallholder producers who dominate the agricultural sector (FAO, 2017; Girei et al., 2018).

With the ban on maize importation into Nigeria, small-scale farmers have a comparative advantage and a greater opportunity to expand maize production output, thereby increasing profitability. Hence, enhancing efficiency in maize production is crucial and timely, leading to higher returns. In the 2020/2021 marketing year, Nigeria reportedly imported an estimated 200,000 tonnes of maize to meet domestic demands (FAO AMIS, 2022). The relatively low productivity of maize in Nigeria can be attributed to various factors, including the cultivation of poor-quality varieties and inadequate government support for small-scale farmers, who constitute the majority. For instance, while Nigeria's average maize yield is around 2.55 tonnes per hectare (t/ha), South Africa and Ethiopia, the largest and third-largest producers in Africa, achieve average yields of 4.9 t/ha and 4.2 t/ha, respectively (PwC, 2021; FAO AMIS, 2022).

Furthermore, maize production in Nigeria is heavily concentrated in the northern region, with the North-East, North-West, and North-Central ecological zones collectively contributing 73.57% of the country's total production (NAERLS and FMARD, 2020). This regional disparity results in higher maize costs for human consumption, its by-products, and livestock feed, thereby discouraging animal production, especially in the southern regions that heavily rely on the North for supplies. Given these challenges, there is a pressing need to efficiently allocate resources in maize production to bridge the productivity gap. Although studies (Abubakar and Sule, 2019; Ayinde and Aminu, 2015; Ebuikiba et al., 2020; Etim and Okon, 2013; Fasakin and Akinbode, 2019; Hassan et al., 2014; Kasim et al., 2014; Olarinde, 2011) have been conducted on the technical efficiency of maize production, not much work has been done on the subject matter in Ondo State. Therefore, this study aims to identify how efficient the farmers are in allocating resources to maximize productivity and investigate the factors contributing to technical inefficiency, which leads to the low productivity of maize in Ondo State, Nigeria. Thus, the study was designed to;

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(i) determine the technical efficiency level of maize production,
(ii) identify the factors influencing technical efficiency of maize farmers, and
(iii) identify the determinants of technical inefficiencies among maize farmers in the study area.

METHODOLOGY

Study Area

The study was carried out in Ondo State, Nigeria. The state is situated between longitudes 4° 30' and 6° East of the Greenwich Meridian, and between latitudes 5° 45' and 8° 15' North of the Equator. Covering an area of approximately 14,788.723 square kilometres, the state is located entirely within the tropics. Ondo State shares its northern boundary with Ekiti and Kogi States, its eastern boundary with Edo State, its western boundary with Osun and Ogun States, and its southern boundary with the Atlantic Ocean (Oparinde and Daramola, 2014).

The state features three distinct ecological zones: the mangrove forest in the south, the rainforest in the central region, and the savannah in the north. Annual rainfall varies from 2,000mm in the southern areas to 1,200mm in the northern areas, with the rainy season occurring from March to October (Oladapo et al., 2012).

Sampling Procedure and Sample Size

Primary data was collected with the aid of a structured questionnaire administered to maize farmers in the study area to obtain data on the estimation of technical efficiencies included physical quantities of production inputs (fertilizers, manures, labor, seeds, and land area under maize) and maize output. The multistage sampling procedure was employed in selecting respondents for this study. The first stage involved the purposive selection of Ondo state out of the six states in South-Western Nigeria based on the high production of maize in the region. In the second stage, three (3) Local Government Areas were randomly selected from the state. In the third stage, five (5) villages were purposively selected from each Local Government Area identified in stage 2 based on the relative intensity of maize farmers in the village as specified by ADP in the state to give a sub total of fifteen (15) villages for the study. In the fourth stage, twenty (20) smallholder farmers were randomly selected in each of the villages. In all, a total of three hundred (300) smallholder maize farmers were interviewed for the study. However, due to inadequate information given by the respondents, 227 were found useful for analysis The simple random sampling selection was carried out with the aid of random numbers generated by a calculator in order to avoid selection/researcher’s bias.

Analytical Technique

The Stochastic Frontier Production Function using the Cobb-Douglas functional form was used in determining the technical efficiency levels of maize farmers in the study area. The Stochastic Frontier Production Function has been used by various researchers (Erhabor and Emokaro, 2007; Ndubueze-Ogaraku and Ogbonna, 2016; Orewa and Izekor, 2012) in assessing the efficiency level of farmers. The Stochastic Frontier Production Function Model is expressed implicitly as:

$$Y_i = f(X_i; \beta) + e_i^{V_i - U_i} \quad (1)$$

Where:

Y_i = the quantity of agricultural output (Kg)
X_i = the vector of the input quantities
β = the vector of production function/unknown parameters to be estimated
e_i = the error term, comprising of a random error term V_i and inefficiency component U_i.
Therefore, the model for **Technical Efficiency** of maize farmers is specified as:

$$\ln Y_{ij} = \beta_o + \beta_1 \ln x_{ij} + \beta_2 \ln x_{2ij} + \beta_3 \ln x_{3ij} + \beta_4 \ln x_{4ij} + \beta_5 \ln x_{5ij} + V_{ij} - U_{ij} \quad (2)$$

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Where:

ij is the j^{th} observation of the i^{th} farmers,

ln = logarithm to base e,
Y = output of the maize farmers produced (kg grain equivalent) per/ha
x_1 = farm size (in hectares)
x_2 = quantity of seed used (in kg/ha)
x_3 = labour used in production (in man-days/ha)
x_4 = quantity of agrochemicals used (in litres/ha)
x_5 = quantity of fertilizer used (in litres/ha)
β_0 to β_5 are the parameters to be estimated.

The technical efficiency of individual farmers was determined by comparing their actual output (Y_i) with the maximum possible output (Y_i^*) achievable with the given technology, such that **$0 \leq TE \leq 1$** as given below:

$$TE = \frac{Y_i}{Y_i^*} = \frac{E(Y_i|U_i, X_i)}{E(Y_i|U_i = 0, X_i)} = E[\exp(-U_i|\varepsilon)] \qquad (3)$$

TE ranges from zero (0) to one (1). As such, value of one (1) for this study indicates that the maize farmer is completely efficient, while a value of zero (0) indicates complete inefficiency.

The technical inefficiency (TI) effects U_i is given by:

$$U_{ij} = \delta_o + \delta_1 z_{1ij} + \delta_2 z_{2ij} + \delta_3 z_{3ij} + \delta_4 z_{4ij} + \delta_5 z_{ij} + \delta_6 z_{6ij} + \delta_7 z_{7ij} \qquad (4)$$

Where:

U_{ij} = TI of the i^{th} farmer,
z_1 = age of the respondents (in years),
z_2 = sex of the respondent, (male or female)
z_3 = marital status (unmarried and married),
z_4 = household size (number of persons in farmers household)
z_5 = education level (in years),
z_6 = farming experience (in years),
z_7 = extension contacts (Number of meetings)
δ_1 to δ_7 are parameters to be estimated.

RESULTS AND DISCUSSION

Estimates of the Technical Efficiency of Small-Holder Maize Farmers in the Study Area

Table 1 shows the technical efficiency of maize farmers in Ondo State. The independent variables (inputs) are, farm size, seeds, labour, agrochemicals, and fertilizer. The value obtained for variance (sigma squared), σ^2 was 0.668 which was significant at 1% level of significance implying that the model is a good fit to the data with less unexplained variability. The result also showed Gamma, γ was 0.3522 implying that 35.2% of the total variation in maize output is due to the technical inefficiency of the farmers. The result also indicated a loglikelihood value of - 247.2584 which implied that the model fits the data better and provides a more accurate representation of the relationship between the input variables and the output variable in the production function. In general, the higher the loglikelihood value, the better the model fits.

Farm Size (X_1)

The result revealed that the coefficient for farm size, X_1 (1.7035), was positive, indicating that an increase in farm size leads to higher maize production. This coefficient was also significant at the 5% level, indicating that

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it is a major factor influencing maize production levels in the study area. This finding aligns with Abdulaleem et al. (2019), who examined maize production efficiency among smallholder farmers in Southwest Nigeria. They found a positive and significant coefficient of farm size (0.702) at the 5% significance level.

Seeds (X_2)

The result also indicated that the coefficient for maize seed, X_2, has a positive and statistically significant effect at the 1% level. This suggests that an increase in the quantity of maize seed leads to a corresponding increase in maize output for farmers. Seed is a fundamental farm input, and proper management can significantly impact overall output. The quantity of seed used is crucial in determining output levels, with maize seed specifically having a substantial influence on productivity. These findings align with previous research by Abdulaleem et al. (2019), which also found a positive relationship between maize seed inputs and maize output.

Labour (X_3)

The coefficient associated with labour, denoted as X_3, was identified as positive and statistically significant at the 1% level of significance. This signifies that an increase in the number of labourers is linked to a corresponding increase in output levels. The study shows a direct and significant relationship between labour input and maize output, establishing labour as a key determinant of maize farmers' output levels in the study area. These findings are consistent with prior research conducted by Getachew and Bamlak (2014) and Ebukiba et al. (2020), whose work showed that the coefficient of labour influences an increase in crop output as a decrease in output is anticipated with reduced labour input.

Agrochemicals (X_4)

Furthermore, the results showed that the coefficient for agrochemicals (X_4) was positive but not significant. This implies that while the application of agrochemicals has a positive relationship with maize output in the study area, it is not a major determinant of maize production. This aligns with the expectation that increased pesticide application can boost productivity, although it is not a significant factor in this case. This finding conforms to the results of Ebukiba et al. (2020) in their study on the economics and technical efficiency of maize production among small-scale farmers in Abuja, Nigeria, using the Stochastic Frontier Model Approach.

Fertilizer (X_5)

The results revealed that the coefficient for the Fertilizer application (X_5) was positive and statistically significant at the 10% level. This indicates that increasing fertilizer results in an increase in farmer production. The significance level of 10% suggests that fertilizer was a substantial determinant of maize farmers' output in the study area. The results are consistent with the findings of Olubunmi-Ajayi et al. (2023), who found the coefficient of fertilizer to be positive and significant at 10% level among maize farmers in Ondo state.

Table 1: Stochastic Frontier Model: MLE (Parameters**) for Technical Efficiency**

Independent Variables	Parameters	Coefficient	Standard Error	z-ratio
Constant	β_0	0.0686	1.7838	0.040
Farm Size (X_1)	β_1	1.7035	0.7365	2.310**
Seeds (X_2)	β_2	0.4134	0.1270	3.250***
Labour (X_3)	β_3	0.5399	0.1580	3.420***
Agrochemicals (X_4)	β_4	0.1285	0.2460	0.520
Fertilizer (X_5)	β_5	0.1110	0.0646	1.720*
Sigma squared (σ^2)		0.6687	0.1084	6.1667***

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Gamma (γ)		0.3522		
Log Likelihood		**- 247.2584**		
Sample size (n)	**227**			

***** Significant at 1% level**

**** Significant at 5% level**

*** Significant at 10% level**

Technical Efficiency Score Among Small-Holder Maize Farmers in the Study Area

The distribution of individual maize farmers according to their technical efficiency (TE) level is presented in Table 2. The results showed that the TE of maize farmers in the study area ranged between 0.152 and 0.859, with an average value of 0.709. This indicates that, on average, farmers are able to achieve 70.9% of the maximum possible maize yield using the resources and technologies available to them, suggesting a moderate level of efficiency. Thus, maize yield could be increased by 29.1% with the existing level of resources if farmers operated at the production frontier. This result is similar to the findings of Aboki et al. (2020) and Muhammed-Lawal et al. (2009), where the mean TE score of maize farmers in their studies was 87.2% and 85.23%, respectively

Table 2: Distribution of Maize farmers according to their Technical Efficiency Score

Technical Efficiency Score	Frequency	Percentages
< 0.41	1	0.44
0.41 – 0.50	4	1.76
0.51 – 0.60	2	0.88
0.61 – 0.70	96	42.29
0.71 – 0.80	110	48.46
0.81 – 0.90	14	6.17
Total	227	100.0
Minimum	0.152	
Maximum	0.859	
Mean	0.709	

Source: Field Survey, 2023

Estimates of Technical Inefficiency of Maize Production: MLE Function

The determinants of technical inefficiency among small-scale maize farmers in the Ondo State are presented in Table 3. The sign of the independent variable's coefficients in the inefficiency model is crucial for explaining the observed level of farmer efficiency. While a positive coefficient has the impact of increasing inefficiency and decreasing efficiency, a negative sign indicates that the explanatory variable has the effect of decreasing inefficiency and increasing efficiency.

The results revealed that age (z_1) had a negative coefficient (-0.2989) significant at the 1% level, indicating older farmers are more efficient in their cultivation processes. This might be due to accumulated experience and knowledge over the years, enabling them to make better decisions and improve farming practices. The result may appear counterintuitive, as older farmers are assumed to have reduced physical abilities and may be unable to work as effectively as younger farmers, as indicated by Abdulaleem et al. (2019), whose work has estimated a positive coefficient for farmer age. One significant aspect to consider is the relationship between farming experience and age. Older farmers typically accumulate more knowledge and expertise in maize farming over the years, enabling them to make better decisions and more efficient farming practices. This accumulated experience often translates into higher yields and reduced inefficiency. Additionally, the sex coefficient (z_2) was positive but not significant, suggesting that female farmers are associated with increased inefficiency compared to male farmers. However, the non-significance indicates that this relationship might be due to chance. Furthermore, marital status (z_3) had a positive coefficient, indicating that married farmers are more efficient. This efficiency is likely due to greater access to labour and financial support, which aligns with a priori expectations. Moreover, household size (z_4) had a negative coefficient, revealing that larger households reduce inefficiency, thus increasing efficiency. This result was statistically significant at the 5% level, supporting the idea that larger households provide more labour resources, and this is consistent with the work done by Dimelu et al. (2009), who found that large household size increases farmer productivity.

The education level (z_5) exhibited a negative coefficient, suggesting that higher education levels reduce inefficiency and increase efficiency, though it was not statistically significant. Education is crucial for economic growth as it equips farmers with better skills and knowledge, enhancing their decision-making and farming practices. Education is also widely recognized as a pivotal driver of economic growth and development, as it equips individuals with the knowledge and skills necessary to enhance their economic well-being. Farmers with higher levels of education possess superior abilities in reading, writing, and comprehending the maize market and farming conditions compared to those with lower levels of education. Additionally, farming experience (z_6) had a negative coefficient (-0.1961) but was not significant, indicating more experienced farmers are more efficient, likely due to better management of pests, diseases, and resources. However, just like educational level, it is not a major factor influencing inefficiency in the study area. Lastly, extension contacts (z_7) had a negative and significant coefficient at the 5% level, showing that increased interaction with extension services decreases inefficiency and boosts efficiency. Extension services provide valuable knowledge and tools for improving farming methods and this result is in line with Abdul-Hanan and Abdul-Rahaman (2017).

Table 3: Determinants of Technical inefficiency among Small-scale maize farmers in the Ondo State

Independent Variables	Parameters	coefficient	Standard error	t-ratio
Constant	δ_0	-50.1249	22.9424	-2.1848**
Age (z_1)	δ_1	-0.2989	0.1031	-2.8997***
Sex (z_2)	δ_2	1.0608	2.0975	0.5058
Marital Status (z_3)	δ_3	12.2634	8.0103	1.5310
Household Size (z_4)	δ_4	-3.1708	1.3195	-2.4030**
Education level (z_5)	δ_5	-0.1426	0.1569	-0.9089
Farming experience (z_6)	δ_6	-0.1961	0.2689	-0.7293
Extension Contacts (z_7)	δ_7	-2.4864	1.0093	-2.4636**

***** Significant at 1% level**

**** Significant at 5% level**

CONCLUSION AND RECOMMENDATIONS

The study established that small-holder maize farmers in Ondo State exhibit significant variability in technical efficiency, with scores ranging from 0.152 to 0.859 and an average efficiency of 0.709, indicating substantial potential for yield improvement. Key inputs such as farm size, seeds, labour and fertilizers were found to significantly enhance maize output. The study also established that major factors influencing inefficiency of the maize farmers in the study area were Age, Household Size, and Extension Contact.

It was therefore recommended that

(i) Given the significant positive impact of farm size and seed quantity on maize output, policies by relevant stakeholders should focus on enabling farmers to access larger plots of land and high-quality seeds. This could involve land reform policies, provision of improved seed varieties, and subsidies for seed purchases.
(ii) Since older and more experienced farmers tend to be more efficient, government and other relevant stakeholders should establish programs that leverage their knowledge and experience. Mentorship programs where experienced farmers train younger ones could enhance overall efficiency.
(iii) Finally, given the significance of extension services in reducing inefficiency, maize farmers in the study area should be provided with regular, practical, and research-based advice by extension agents in order to improve farming practices and efficiency.

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