RESEARCH ARTICLE Agricultural Reviews, Volume 47 Issue 2: 311-317 (April 2026)

Efficiency Measure (Technical and Profit) in Cucumber (*Cucumis sativus* L.) Production among Small Holder Farmers in South-South Nigeria

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10.18805/ag.RF-384

ABSTRACT

Background: Efficiency measure (technical and profit) in cucumber (*Cucumis sativus* L.) production among small holder farmers in South-South Nigeria was conducted. Technical and profit efficiencies are indicators of overall efficient production. Cucumber can contribute to economic empowerment if efficiently produced due to the high relative unit price of the crop.

Methods: Multi-stage random sampling techniques (three-stage) was adopted in the selection of respondents for the study. The data collected for the study were analyzed using stochastic frontier production function model for objectives one and two and stochastic frontier profit function model to realize objective three.

Result: Result of analysis showed that technical efficiency of sampled cucumber farmers was less than 1, implying that the farmers were producing below the maximum frontier output. The least technically efficient cucumber farmers had a technical efficiency of 0.32 and the most technically efficient ones had 0.94. Cucumber seedlings, labour and fertilizers were positive and significant at 5%, to affect technical efficiency of cucumber farmers and agrochemical at 1%. For technical inefficiency of cucumber farmers, age of farmers and farm size were negative and significant at 5% level, while household size, educational qualification, non-farm income and farming experience were positive and significant at 5% level and type of cropping was positive and significant at 10% level. Determinants of profit efficiency of cucumber farmers showed that age (0.37) was positive and significant at 1% level. A direct and significant relationship was found between education (0.67) and profit inefficiency of the farmers. Experience (-0.21) was negative and significant, household size (0.58) was positive and significant at 10% level. The following were recommended: farmers should invest in cucumber production for its efficiency, profitability and economic value.

Key words: Cucumber, Profit efficiency, Resource use, Stochastic frontier, Technical efficiency.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a widely-cultivated creeping vine plant in the family *cucurbitaceae* that bears cylindrical fruits, which are used as culinary vegetables. The crop roots in the ground and grows up on supported frames,wrapping around supports with thin, spiraling tendrils. Qamar *et al.* (2016) noted that the plant may also root in a soilless medium, whereby it will sprawl along the ground instead of a supporting structure. The vine has large leaves that form a canopy over the fruits, which consist of 95% water and is rich in nutrients, low in calories but high in many important vitamins and minerals. Cucumber contains antioxidants, promotes hydration and may aid in weight loss and lowers blood sugar among other health benefits (Zheng *et al.,* 2019). It is real versatile vegetable because of variety in their use from salad to pickles as well as from digestive aids to beauty products. It was found useful against human constipation and improvement in digestion aa well as used as a cooling food in summer. A fresh cucumber provides vitamin C, niacin, iron, calcium, thiamine, fibers and phosphorus. Cucumber is an essential part of agriculture in the area because it is considered a source of livelihood and income. This is why the plant has made significant incursion into the diets of small holder farmers of the study area and hence underscores the need for this study. The fruit of typical cultivars of cucumber is roughly cylindrical, but elongated with tapered ends and may be as large as 62 centimeters (24 in) long and 10 centimeters (4 in) in diameter (Fig 1).

Technical and profit efficiencies are indicators of overall efficient production, with attendants benefits to the farmer and society (Abdulai and Eberlin, 2001 and Meena, 2024). The efficiency, with which farmers use available resources and improved technologies, is important in agricultural

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How to cite this article: Ettah, O.I., Uwah, E.E., Edet, E.O., Fakuta, B.A. and Ettah, G.I. (2026). Efficiency Measure (Technical and Profit) in Cucumber (*Cucumis sativus* L.) Production among Small Holder Farmers in South-South Nigeria. *Agricultural Reviews.* **47(2):** 311-317. doi: 10.18805/ag.RF-384.

Submitted: 04-04-2025 **Accepted:** 21-10-2025 **Online:** 03-11-2025

production Agbachom *et al.* (2022). According to Ettah *et al.* (2020) the efficient use of farm resources is an important part of agricultural sustainability and a prerequisite for optimum farm production. The authors went on to assert that inefficiency in resource use can distort food availability and security. Efficiency measurement as it is being studied here is important because it leads to substantial resource savings and good profit margins. Ettah and Ani. (2018) noted that technically efficient production is defined as the maximum quantity of output attainable by a given input. But Cechura *et al.* (2014) and Jinghan (2009) noted that technical efficiency is the ability of a firm to maximize output for a given set of resource inputs. Profit efficiency on the other hand overcomes the traditional measures of a farm's performance such as return on investment (ROI) and provides an innovative way of performance measure (Jondrow *et al.,* 1982). This efficiency measures the farmer's ability or that of the farm to manage its resources and produce outputs with greater economic value and hence more income to the farm, this is why it is considered the better predictor for evaluating the overall performance of farm production (Adenuga *et al.,* 2013 and Kumar and Kumar, 2023).

Cucumber can contribute to economic empowerment if efficiently produced due to the high relative unit price of the commodity compared to local fruit vegetables. Inefficiency in the use of available scarce resources for the crops' production has been the bane of increased production of the crop in the area. Crop productivity depends on the efficient use of resources used in its production process. Empirical studies on the technical and profit efficiencies of vegetables in various regions of Nigeria focused on tomato, pumpkin and watermelon. None of the studies examined the economics and determinants of the technical and profit efficiencies of cucumber production in the study area. It is against this backdrop that this study was conducted and sought to realize the following specific objectives:

i. Estimate the technical efficiency of cucumber farmers.
ii. Determine the factors affecting technical efficiency.
iii. Examine the determinants of profit efficiency of cucumber farmers.

MATERIALS AND METHODS

This research study was conducted between 2022 to 2025 and the analysis carried out in the Department of Agricultural Economics Econometric Centre of the University of Calabar, Nigeria. The rationale of the study being to estimate the overall efficiency of cucumber production in South-South Nigeria (SSN).

Study area

The study area is (SSN) in West Africa and purposively chosen for its large-scale contribution to Nigeria's cucumber production and the peculiarity of efficiency related problems in the region. The region is one of the six geopolitical divisions of Nigeria, a country on the Gulf of Guinea and regarded as the most populous in Africa and the sixth in the world (NEEDS, 2022). It comprises six states as follows: Akwa Ibom, Bayelsa, Cross River, Edo and Rivers.

The region stretches along the Atlantic seaboard from the Bight of Benin coast in the west to the Bight of Bonny coast in the east. It encloses much of the Niger Delta, which is instrumental in the environment and economic development of the region. Although the South-South represents only 5% of Nigerian territory, it contributes greatly to the Nigerian economy due to extensive agricultural, oil and natural gas reserves. The region has a population of about 26 million people, around 12% of the total population of the country (NPC, 2011). The study area has a tropical climate with variable rainy and dry seasons, with mean annual rainfall between 1,300 mm to 3,000 mm and temperature range of 23°C and 37°C. According to Central Bank of Nigeria (CBN) (2012) the vegetation of South-South region parades four distinct features: Mangrove Swamp (wetland), rainforest, derived savannah and parkland. The type of soil found in the area is deep laterite fertile and dark clayey basalt suitable for agricultural production.

Sampling procedure and data collection

Multi-stage random sampling techniques (three-stage) was adopted in the selection of respondents for the study. The six States of the region which reflected the demarcation structure of the area were covered. In the first stage, three States were selected randomly from the six States of the region, the criteria for the selection were the States with preponderance of cucumber production. The second stage involved the random selection of three Local Government Areas (LGA's) in the three states earlier selected making a total of nine local government areas in the sample. The third stage involved a random selection of ten cucumber farmers from each of the nine LGA's previously selected giving a total of 120 respondents for the study.



Fig 1: Cucumber fruit.

Data required for this study were generated from primary sources. The primary data were collected using a set of pre-tested structured questionnaires. The questionnaires were administered by well-trained enumerators (farmers), who were conversant with the selected locality. Primary data were also obtained through personal contact, oral interviews, *etc*. A pilot study was conducted as adopted by Agbachom *et al.* (2023) where enumerators were used for pre-testing of the questionnaire. This was to avoid inconsistency and incomplete response and also ensure clear understanding of the instrument as well as possession of both face and content validity. In other to check the consistency of the measuring instrument over time, reliability test was conducted using the test-retest method. The same questionnaires were given to the same respondent at two points in time (an interval of seven days) and the scores were compared.

Data analysis

The data collected for the study were analyzed using stochastic frontier production function model for objectives one and two and stochastic frontier profit function model to realize objective three. The models were specified as follows:

Stochastic frontier production function model for technical efficiency in cucumber farmers

The production technology of the cucumber farmers was assumed to be specified by the Cobb-Douglas frontier production function. Following Ettah *et al.* (2020), as cited in Bravo-Ureta and Rieger (1991), the Cobb-Douglas stochastic frontier production function model used was explicitly specified as:

$$l_nY = \beta_o + \beta_1 l_n x_1 + \beta_2 l_n x_2 + l_3 L_n x_3 + \beta_4 l_n x_4 + \beta_5 l_n x_5 + \beta_6 l_n x_6 + - U_1 \quad ...(i)$$

Where,

l_n = Logarithm to base.
Y= Output of cucumber (Kg).
x_1= Cucumber seeds (kg).
x_2= Hired labour (₦/man day).
x_3= Fertilizer (kg).
x_4= Agrochemicals (₦).
x_5= Farm size (Hectare).
x_6= Capital inputs (₦).
β_o = Constant term.
β_0-β_1..... β_6 = Regression coefficients.
U_i= Random errors which were assumed to be independent and identically distributed having N (0, δ^2).
U_i= Non-negative random variables associated with technical inefficiency.

It is assumed that the technical efficiency effects are independently distributed and arise by truncation at (zero) of the normal distribution with mean U_1 and variances δ^2, where U_1 is specified thus;

$$U_i = \delta_0 + \delta_1 z_1 + \delta_2 z_{2i} \delta_{3i} z_{3i} + \delta_4 2_{4i} + \delta_5 z_{5i} + \delta_6 z_{6i} + \delta_7 z_{7i} + \delta_8 z_{8i} + \Sigma \quad ...(ii)$$

U_i = Technical inefficiency of the i^{th} farmer.
Z_1= Age of farmer (years).
Z_2= Level of education (No of years spent in school).
Z_3= Farming experience (years).
Z_4= Household size (number).
Z_5= Extension contact (number).
Z_6= Credit status (dummy variable, 1 for access, zero otherwise).
Z_7= Membership of cooperative (1 for membership, zero otherwise).
Z_8= Sex (binary variable, male = 1, female = 0).
Σ = Error term.
δ_0 - δ_8= Parameters.

The above model was incorporated in the frontier model in determining the technical inefficiency of cucumber farmers. This was done with the belief that the variables have direct influence on the level of efficiency (Ettah and Ani, 2018) as cited in Battesse and Cora (1993) and Kalisajan and Shad (1994).

Stochastic frontier profit function model

The stochastic frontier profit function was used to achieve objective three as earlier stated using Cobb-Douglas functional form which was specified as follows:

Cobb-Douglas

$$l_n \pi = \beta_{oY^*} + \beta_1 l_n x_1 + \beta_2 l_n x_2 + l_3 L_n x_3 + \beta_4 l_n x_4 + \beta_5 l_n x_5 + \beta_6 l_n x_6 + V - U_1. \quad ...(iii)$$

ln= Logarithm to base.
π = Profit of cucumber (₦).
X_1= Land rent per ha.
X_2= Cost of hired labour used in cucumber production per ha.
X_3= Price of cucumber seedlings (₦).
X_4= Price of Agrochemical per litre.
X_5= Price of fertilizer per kg.
X_6= Price of capital inputs (₦).
U_1= Error term.
β_o= Constant term.
β_1-β_2 ..... β_6 = Regression coefficients.
V_i = Random variables which are assumed to be independent of Ui and normally distributed with zero mean and constant variance Vi-N (0, δ^2) which are non-negative random variables and are assumed to account for technical inefficiency in production and are often assumed to be independent of V_i, such that U is the non-negative truncated (at Zero) U of half normal distribution with { N (0, δ^2)}.
The determinant of profit inefficiency is defined by:

$$Ui = \delta_0 + \delta_1 z_1 + \delta_2 z_{2i} + \delta_3 i z_{3i} + \delta_4 z_{4i} + \delta_5 z_{5i} + \delta_6 z_{6i} + \delta_7 z_{7i} + \quad ....(iv)$$

Where,

Ui= Cucumber profit inefficiency.
Z_1= Farmers' age (years).
Z_2= Farming experience (years).
Z_3= Education (years).
Z_4= Training (1 if received training, 0 otherwise).
Z_5= Membership of farmers' association (1, yes, 0, no).
Z_6= Household size (no. of persons).

Z_7= Sex (1, Male, 0, Female).
δ_0 - δ_7= Parameters.

RESULTS AND DISCUSSION

Estimation of technical efficiency of cucumber farmers

A very important characteristic of production frontier model is its ability to estimate technical efficiency of production. The result is as shown in Table 1 indicated that, technical efficiency of sampled farmers is less than 1. This implies that cucumber farmers are producing below the maximum frontier output. The range of technical efficiency showed that 1.7% of the farmers had technical efficiency between the range of 0.31-0.40 and 0.41- 0.50 respectively, 5.0% had technical efficiency of 0.51-0.60, 12.5% had technical efficiency of 0.61-0.70, 61.7% had technical efficiency of 0.71-0.80, 15.8% had technical efficiency of 0.81- 0.90 and again 1.7% had technical efficiency of 0.91-1.00. The least technically efficient farmer had a technical efficiency of 0.32 which means that the farmer has to increase his level of production given his inputs and technology to at least 68% for him to operate at the production frontier while the most technically efficient farmer had technical efficiency of 0.94 which means that he has to increase his production at least by 6% for him to operate on the production frontier and be fully efficient. The mean technical efficiency was 0.72; this implies that all sampled farmers will need to increase production at least by 28% given the available mix of inputs at a given technology for it to operate on the production frontier. The mean of the worst 10 technically efficient farmer was 0.52 while the mean of the best 10 technically efficient farmer had a technical efficiency of 0.9. The result is in line with that of Adeyemo and Kuhlmann (2009) and Ayinde *et al.* (2011) in their study of resource use efficiency in urban agriculture in Southwestern Nigeria and resource use efficiency and profitability of fluted pumpkin production under tropical conditions respectively, but contravenes that of Ettah *et al.* (2022) and Meena (2024) in their study resource use in sweet potato production in Delta State, Nigeria.

Factors affecting technical efficiency of cucumber farmers

Result of factors affecting technical efficiency are shown in Table 2 shows the result of the maximum likelihood estimates (MLEs) of the stochastic frontier production function for cucumber farmers. The estimates of sigma squared (σ^2) for cucumber farmers were 4.3672. This was significant at 5% probability level, indicating that it is significantly different from zero. It assures us of the goodness-of-fit as well as the correctness of the composite error term. The value of the gamma (γ) 0.7619 showed that the unexplained variation in output of cucumber farmers is the major source of random errors. It also indicates that about 76 per cent of the variation in output of cucumber is caused by inefficiency of the producers. This result confirms the presence of one-sided error components in the model and hence makes the use of ordinary least square (OLS) inadequate in estimating the production function.

The estimates of the parameters of the production function are; cucumber seedings, labour and fertilizers which were positive and significant at 5%, this implies that an increase or decrease in seedlings, labour and fertilizer will result to a corresponding increase or decrease in output of cucumber farmers respectively. Agrochemical was found to be positive and significant at 1% level of significance while capital input was positive and not significant. Factors affecting technical inefficiency of cucumber farmers are shown in the lower part of Table 2. Age of farmers and farm size were negative and significant at 0.05 levels of probability, while household size, educational qualification and farming experience were all positive and significant at 5% levels of significance and type of cropping was positive and significant at 10% level of significance. Non-farm income was positive and significant at 5% level of probability. This means that unit increase in these variables would increase technical inefficiency of the farmers and hence decreasing their technical efficiency. The larger the household size the more resources are diverted to non - farm activities like medical care, education, welfare, *etc*. This development causes farmers to be inefficient in the use of these resources for cucumber production. The result agrees with findings of Cechura *et al*. (2014) that family demands affect the efficient use of resources to farm production.

The more farmers are educated, the more they turn away from cucumber farming, to other businesses perceived to bring quicker returns on investment. The less educated ones who cannot efficiently utilize resources dominate the farm industry. Highly experienced farmers tend to stick to their old methods of production which may be inefficient (Ettah *et al.,* 2022). Cucumber farmers do not invest their non-farm income in their farm, they rather channel the income to high returning investments. This result agrees with that of Sagar *et al.* (2023) who found out

Table 1: Technical efficiency distribution of cucumber farmer.

Efficiency level	Frequency	Percentage
0.31-0.40	2	1.7
0.41-0.50	2	1.7
0.51-0.60	6	5.0
0.61-0.70	15	12.5
0.71-0.80	74	61.7
0.81-0.90	19	15.8
0.91-1.0	2	1.7
Total	120	100.0
Minimum	0.31	
Maximum	0.95	
Mean	0.72	
Mean of worst 10	0.52	
Mean of best 10	0.9	

Source: Field survey 2024 analysis of output from frontier 4.1c.

that farmers give priority to investments outside agriculture because they are relatively fast in return to capital.

Determinants profit efficiency of cucumber farmers

The parameter estimates of the determinants of profit efficiency of cucumber farmers are presented in the upper and lower section of Table 3 respectively.

The analysis of profit inefficiency effect showed a significant gamma (γ = 0.83). This implies that 83% deviation from maximum profit obtainable was as a result of inefficiency of the cucumber farmers rather than random error or variability. The signs and significance of the estimated coefficients in the inefficiency model have important implications on profit efficiency of the farmers. The estimated coefficient for age (0.37) was positive and significant at 1% level. The positive relationship implies that as age of cucumber farmers increases, the level of profit inefficiency tends to increase thereby decreasing profit efficiency. This could be that as the cucumber farmers get older, the less efficient his labour, managerial abilities and supervision. This finding is in line with the work of Cechura *et al.* (2014) and Tanko and Adeniyi (2012) where age positively contributed to profit inefficiency. A direct and significant relationship was found between education (0.67) and profit inefficiency of cucumber farmers. This implied that an increase in the level of education increased the level of profit inefficiency (*i.e*. decrease profit efficiency). The positive value obtained is unexpected as cucumber farmers may go in search of white-collar jobs thereby neglecting cucumber farming or paying little or no attention to it. This finding disagrees with the work of Ettah and Ani (2018) and Dey *et al.* (2000) that education decreases profit inefficiency in rice farming. The findings agree with that of Adeyemo and Kuhlmann (2009) and Ayinde *et al.* (2011) that education increases profit inefficiency in crop farming. The estimated coefficient for farming experience (-0.21) was negative and significant implying that, increase in farming experience tends to decrease the level of profit inefficiency (*i.e*. increase profit efficiency). This finding is in consonance with the findings of Qamar *et al.* (2019) who found that increase in farming experience decrease profit inefficiency of farmers in their study: analysis of off-season cucumber production efficiency in Punjab, India.

Household size (0.58) had positive and significant relationship with profit inefficiency at 10% probability level. This implies that, increase in household size increases profit inefficiency (*i.e*. decrease profit efficiency) of cucumber farmers. This result is in congruence with findings of Etim *et al.* (2005) who observed a positive relationship between household size and profit efficiency in urban farms in Uyo Metropolis of Akwa Ibom State, Nigeria. This is however contrary to the findings of Adenuga *et al.* (2013) who found household size to increase profit efficiency among dry season tomato producers in selected areas in Kwara State, Nigeria. The result further showed a negative and significant relationship between membership of association and profit inefficiency. Membership of association decreases profit inefficiency and rather

Table 2: Factors affecting technical efficiency.

Variable	Coefficient	Standard error	t
Constant	-0.5906	0.2960	-1.9951**
seedlings	0.6543	0.2956	2.213**
Labour	10.03858	4.7484	2.1141**
Agrochemicals	0.6105	0.1819	3.5514*
Capital input	0.5314	47.4464	0.0112
Fertilizer	18.5603	9.3303	1.9892**
Variance measures			
Sigma-squared	4.3672	1.3312	3.2714
Gamma	0.7619	0.0873	9.1415
Log likelihood function	-301.50098		
Technical inefficiency model			
Age	-0.0053	0.0025	-2.1211**
Sex	0.0032	0.0024	1..3112
Occupation	-0.0524	0.0531	- 0.9861
Household size	1.5643	0.7895	1.9812**
Educational qualification	0.0612	0.0275	2.2234**
Farming experience	2.1777	1.0123	2.1512**
Farm size	-0.2212	0.1042	2.1213**
Non-farm income	0.2689	0.1345	1.998**
Type of cropping	0.2069	0.2065	1.0021

*,**, Significant at 1% and 5% level respectively.

Source: Field survey, 2024.

Table 3: Determinants of profit efficiency and inefficiency cucumber farmers.

Variable	Coefficient	Standard error	t-ratio
Efficiency model			
Constant	9.22	1.29	7.13*
Output	0.57	0.07	8.34*
Land rent per ha	-0.94×10^{-2}	0.072	-0.13
Hired labour per ha	-0.72×10^{-2}	0.001	-0.69
Seedlings per Kg	0.68×10-2	0.035	0.19
Agrochemical price per ha	-0.07	3.5	-0.02
Inefficiency model			
Constant	-38.40	6.26	-6.13*
Age	0.37	0.092	4.03*
Farming experience	-0.21	0.047	2.08**
Education	0.67	0.058	12.54*
Number of training	5.61	1.021	5.73*
Member of Association	-8.06	2.420	3.33*
Household size	0.58	0.243	1.81***
Sex	0.16	0.197	0.81
Variance parameters			
Sigma Squared	18.66	1.842	10.13
Gamma	0.83	0.52×10^{-2}	163.19
Likelihood function	-188.34		

Source: Field survey, 2024.

*,** = t ratio significant at 1% and 5% level respectively.

increases profit efficiency. This is expected as cucumber farmers' membership of association could afford them the opportunity of interacting with other farmers thereby exchanging information on improved technology in arable crop farming. Although the result disagrees with the findings of Kuye and Ettah (2016) and Goni *et al.* (2013). In conclusion, age, education and household size had positive impact on profit inefficiency and this is contrary to *apriori* expectation regarding the roles of these factors.

CONCLUSION

Technical efficiency of sampled cucumber farmers was less than 1, implying that the farmers were producing below the maximum frontier output. The least technically efficient cucumber farmers had a technical efficiency of 0.32 which meant that the farmers have to increase their level of production given the available inputs and technology to at least 68% for them to operate at the production frontier. The most technically efficient cucumber farmers had technical efficiency of 0.9. Cucumber seedlings, labour and fertilizers were positive and significant at 5%, to affect technical efficiency of cucumber farmers and agrochemical at 1% level of significance. For technical inefficiency of cucumber farmers, age of farmers and farm size were negative and significant at 5% level of significance, while household size, educational qualification, non-farm income and farming experience were all positive and significant at 5% levels of significance and type of cropping was positive and significant at 10% level of significance. Estimates of the determinants of profit efficiency of cucumber farmers showed that age (0.37) was positive and significant at 1% level. A direct and significant relationship was found between education (0.67) and profit inefficiency of cucumber farmers. Experience (-0.21) was negative and significant. Household size (0.58) had positive and significant at 10% level. The result also showed a negative and significant relationship between membership of association and profit inefficiency. Based on the results of the study, the following are recommended: farmers should be encouraged to invest in cucumber production for its technical efficiency, profitability and economic value, inputs should be made available and at affordable price especially new varieties of cucumber seedlings and cucumber farmers should be guided on the type of cropping to undertake so as to increase their technical efficiency.

ACKNOWLEDGEMENT

The authors would like to thank all the authorities of the Department of Agricultural Economics, University of Calabar, Nigeria, for providing their academic support and resources.

Ethical approval

Authors declare that this manuscript does not include any studies using animal and human beings.

Consent to publication

All authors read and approved the final manuscript.

Conflict of interest

On behalf of all authors, I declare that we have no conflict of interests of any sort.

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