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Technical Efficiency and its Determinants in Water Melon Production in Borno State, Nigeria

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Abstract
This Study examined technical Efficiency of Watermelon in Borno State, Nigeria. Primary data collected through the use of structured questionnaire from 120 randomly selected watermelon farmers from six (6) villages in the two local government areas were used. Stochastic frontier production function was used to analyze the technical efficiencies of watermelon farmers. The results of the stochastic frontier function analyses revealed a mean technical efficiencies levels of 86%, implying that there was scope for increasing efficiencies by 14%. The main sources of technical inefficiencies were years of farming experience, extension contact, membership of cooperative societies, amount of credit obtained and educational level. The study recommends that extension contact, years of cooperative membership and access to credit were the sources of the inefficiencies and should be addressed through adequately trained and equipped extension workers, right use of credit facilities and the formation of cooperative societies and making membership a condition for microcredit benefit.

1. Introduction

Vegetable production has been playing a vital role in human nutrition, poverty reduction and improving the socio-economic status of the farmers. Vegetables are important items in the daily diet of the Nigerian family. They are a cheap and easily available source of vitamins, minerals and dietary fibre and are low in fat and calories (Abba, 2004). However, per capita consumption of vegetables in developed countries tends to be higher than in developing countries, possibly because they have a better appreciation of the nutritive value of the crops. There is little chance of malnutrition occurring where enough vegetables are eaten. Malnutrition reduces the working capacity of farmers and their families. In severe cases, serious physical and mental retardation or even death may occur. As a result of reduced working capacity, incomes may decrease and poverty may increase (Asian Vegetable Research and Development Centre, AVRDC, 1990).

Despite the nutritional and commercial value of watermelon, its production remains low in Nigeria (Dauda *et al*., 2008). The productivity of farmers can be raised by adoption of improved production technologies or improvement in efficiency or both. But with the low rate of adoption of improved technologies by farmers in Nigeria, improvement in efficiency becomes the best option in productivity enhancement in the short run (Idiong, 2007). Information on efficiency of production is important because the presence of shortfalls in efficiency means that output can be increased without additional inputs and new technology.

Therefore, there is a need to provide empirical information on farm level production efficiency on small-scale watermelon production. This study is significant as it will contribute to research by bridging the information gap in efficiency studies as most of the previous work focused on agronomic issues (Adekunle *et al*., 2003; Dauda *et al*., 2008; Gambo *et al*., 2008). The objective of this study is to determine the technical efficiency and its determinants in watermelon production in Borno state, Nigeria.

Hypotheses

The hypotheses put forward for this study was:

Ho; there are no technical inefficiency effects in the watermelon farms in Borno State.

Hi; there are technical inefficiency effects in the watermelon farms in Borno State.

The Study Area: The study was conducted in Borno state of Nigeria. Borno State lies between latitude, 10^{o} 02' and 13^{o} 04' N of the equator and longitude, 12 ^{o} 04' and 15 ^{o} 04'E of the Greenwich meridian, and has an area of about 69,436 sq km (BOSADP, 2008). The State shares boundaries with Adamawa State to the South, Yobe State to the West and Gombe State to the South West. It also shares international borders with the Republic of Niger to the North, Chad Republic to the North East and Cameroon to the East. Borno State has twenty-seven Local Government areas (BOSADP, 2008).

The main occupation of the people is farming. The major crops cultivated include cereals like maize, millet, sorghum, rice, and wheat; legumes (groundnut, cowpea, Bambara nuts) and vegetables like tomatoes, amaranthus, pepper, carrot, onions and watermelon (Ehiemere, 2003).

METHODOLOGY

A multistage sampling technique was used for this study. In the first stage two Local Government Areas in the state {Kaga and Kukawa} were purposively selected, being the largest producers of watermelon in the state (Gambo *et al*., 2007). The second stage involved purposive selection of three villages each in the two local government areas based on their intensity of watermelon production and accessibility. These villages were Benisheikh, Ngamdu and Mainok from Kaga local government area and Baga, Doron baga and Dabon Masara from Kukawa local government area. Flip paper method was used in each village; each producer in a village was given a number and was written on paper starting from one. The papers were shuffled continuously until the desired sample size of 120 farmers obtained.

Primary data were used for this study and were collected with the aid of structured questionnaire. The output data includes the total yield of the watermelon produced cash receipts from selling, quantity consumed at home and those given out as gifts. The input data include farm size, quantity of agrochemicals, labour, quantity of seeds, quantity of fertilizers, cost of simple farm tools such as sprayers, cutlass, hoes and other simple farm implements used.

Stochastic Frontier Approach

The modeling, estimation and application of stochastic frontier production functions to economic analysis assumed prominence in econometrics and applied economic analysis during the last two decades. Early applications of stochastic frontier production functions to economic analysis include those of Aigner *et al*. (1977) who applied the stochastic frontier production functions in the analysis of the United States agricultural data. Battese and Corra (1977) applied the techniques to the pastoral zone of Eastern Australia. And more recently, empirical applications of the technique in efficiency analysis have been reported (Ojo and Ajibefun, 2000; Ojo, 2003; Maurice, 2004; Idiong, 2007; Usman, and 2009; Adejoh, 2009.

The stochastic frontier production function was independently proposed by Aigner, *et al*., (1977) and Meeusen and Van den Broeck (1977). The stochastic production function is defined by

$$Y_i = f(x_i; \beta) + e_i \quad \ldots\ldots (1)$$

$$e_i = v_i - u_i \quad \ldots\ldots (2)$$

Where:

Y_i = observed output of the i^{th} sample farm. f ($x_i; \beta$) is a suitable functional form such as Cobb-Douglas, x_i vector of the inputs used by the i-th farm, β vector of unknown parameters to be estimated, e_i is the error term made up of two components: v_i is a random error having zero mean which is associated with random factors outside the farmers control such as topography, weather, measurement errors, disruptions of supplies and is assumed to be an independently and identically distributed N $(0,\delta^2 v)$ random variable and independent of u_i. On the other hand, ui is a non-negative truncated half normal random variable associated with farm –specific factors, which leads to the i-th farm not attaining maximum efficiency of production. U_i is associated with technical inefficiency of the firm and ranges between zero and one. U_i follows an identical and independent half-normal distribution, N $(0, \delta^2 u)$. N represents the number of firms involved in the cross-sectional survey.

The stochastic frontier production function model is estimated using the maximum likelihood estimation procedure (MLE) (Bakhsh, 2007). The technical efficiency of an individual firm is defined in terms of the observed output (Y_i) to the corresponding frontier output (Y_i*) given the available technology.

$$TE_i = Y_i/Y_i^* \quad \ldots\ldots (3)$$

$$TE_i = F(x_i; \beta) \exp(v_i - u_i)/F(x_i;\beta) \exp(v_i) = \exp(-u_i) \quad \ldots\ldots (4)$$

So that $0 \leq TE_i \leq 1$

Therefore, the technical inefficiency is equal to 1 – TÊ

The strength of the stochastic frontier approach is that it deals with the stochastic noise and permits statistical test of hypotheses pertaining to the structure and degree of inefficiencies.

The stochastic frontier model for estimating the technical efficiency of the watermelon farms is empirically specified by the Cobb-Douglas frontier production function as:

$$\text{In}Y_i = \beta o + \beta_1 \text{In}x_1 + \beta_2 \text{In}x_2 + \beta_3 \text{In}x_3 + \beta_4 \text{In}x_4 + \beta_5 \text{In}x_5 + v_i - u_i \quad \ldots\ldots (5)$$

Where:

Yi = Output of watermelon (kg)

In=logarithm to base e

βo = constant or intercept

β_1-β_5 = unknown scalar parameters to be estimated

x_1= quantity of watermelon seeds (kg)

x_2= farm size cultivated (ha)

x_3= quantity of agrochemicals used (litres)

x_4= quantity of NPK fertilizers used (kg)

x_5= labour used (man days)

v_i = random errors

u_i = Technical inefficiency effects predicted by the model

Subscript i indicate the i[th] farmer in the sample.

The technical inefficiency effects U_i is affected by:

$U_i = \alpha_o + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7$…………………………..(6)

Where

Ui = technical inefficiency effects
Z_1 =age of the farmer (years)
Z_2 = farming experience (years)
Z_3 = educational level of farmers (Number of years spent in school)
Z_4 = household size (Number of person)
Z_5 = visits by an extension agent (Number of visits)
Z_6 = years of cooperative membership ( )
Z_7 = Amount of credit received (in Naira)
α_1-α_7 are the scalar parameters to be estimated
α_o = constant or intercept

These were included in the model to indicate their possible influence on the technical.

Likelihood ratio (LR) test

The stated hypotheses ii and iii for the study were tested using the generalized likelihood ratio test.

LR = -2(log likelihood under H_o/log likelihood under H_A) or
= -2(log likelihood under H_o – log likelihood under H_A) ………………………………. (7)

Where Log likelihood H_o and H_A are null and alternative hypotheses, respectively. The degree of freedom is equal to number of restrictions and the number of restrictions is equal to the number of parameters excluded in the unrestricted model. This statistics has approximately chi-square distribution with degree of freedom equal to number of parameters specified to be zero in the null hypothesis. The null hypothesis will be rejected if the calculated LR is greater than the tabulated chi square.

RESULTS AND DISCUSSION

Technical Efficiency of Water Melon farmers

Table 1 revealed the estimates of the parameters for the frontier production function and the variance parameters of the model. The variance parameters Sigma (δ^2) was 0.199 and was statistically significant at 1% level of probability. This indicates a good fit and correctness of the distributional form assumed for the composite error term. The gamma (γ) which is the proportion of deviation from frontier that is due to inefficiency estimate was 0.135 and is statistically significant at 1% it shows the amount of variation resulting from the technical inefficiency of watermelon farmers. This means that more than 13% of the variation in farmers output is due to the difference their technical efficiencies.

The mean technical efficiency of the farmers was 86%. This implies that on the average, the respondents are able to obtain about 86% of potential output from a given mix of production inputs. Thus, in the short-run, there is a scope for increasing watermelon production by 14%, by adopting the technology and techniques used by the best watermelon farmer.

Table 1: Estimates of technical efficiency model for watermelon farmers in Borno state

Variable	Parameter	Coefficient	Std Error	t-ratio
Constant	βo	8.246	0.261	31.660***
Seed (x_1)	βi	0.515	0.067	7.716***
Farm size (x_2)	β2	0.179	0.067	3.112***
Agrochemicals (x_3)	β3	0.140	0.068	2.073**
Fertilizer (x_4)	β4	0.011	0.002	5.615***
Labour (x_5)	β5	0.004	0.039	0.089
Variance Parameters				
Sigma (δ^2)		0.199	0.031	6.468*
Gamma (γ)		0.135	0.019	7.240*
Log likelihood		-45.353		
Mean technical efficiency		0.861		

***, **, * implies significant at 1%,5% and 10% respectively

The estimated coefficient for seed was positive and statistically significant at 1%. The estimated elasticity of production of seed was 0.5 implies that increasing seed by 1 per cent will increase watermelon output by about 0.52 percent. The 0.515 elasticity estimate implies that watermelon output is inelastic to changes in the quantity of seeds, ceteris paribus. The quantity of seed determines to a large extent, the output obtained. If correct seed rates and quality seeds are not used, output will be low even if other inputs are in abundance. This is consistent with the findings of Shehu *et al*. (2010) among Benue Farmers where yam seed rate had a significant positive relationship with yam output.

The estimated coefficient for farm size (0.179) was positive and statistically significant at 1%. The 0.179 elasticity of production of farm size implies that a 1% increase in farm size will, ceteris paribus, lead to an increase of 0.179% in watermelon output. This is consistent with the findings of Adeoti and Olayemi (2003), who found that increasing farm size is expected to increase crop output of *fadama* farmers in northern Nigeria and also Ukun *et al*. (2010) reported a significant positive relationship between farm size and output for garden eggs production in Akwa Ibom state, Nigeria.

The elasticity estimate for agrochemicals was 0.140 and was positive and statistically significant at 5% level of probability. This implies that 1% increase in the use of agrochemical will increase output of watermelon by 0.140%. This is in line with the findings of Adejoh (2009) who reported that the coefficient of agrochemical input was positive and significant among yam producers in Kogi State. The elasticity of production with respect to quantity of fertilizer used was 0.011 and positive and statistically significant at 1%. This implies that a 1% increase in fertilizer will increase output by 0.011%. Fertilizer is a major land augmenting input because it improves the quality of land and the productivity. This study is in agreement with the works of Maurice (2004) who found out that increasing fertilizer, increases output among cereal crop farmers in Adamawa state and Oladiebo and Fajuyigbe (2007) that fertilizer significantly increase output in upland rice cultivation in Osun state. The coefficient of labour was 0.004; it is positive but not significant. This implies that increasing labour will increase output but not significantly.

Frequency Distribution of Technical Efficiency of Watermelon Farmers

Table 2 presents the technical efficiency distribution of the watermelon farms in the study area. The mean technical efficiency of the sampled farmers in the study area was 0.861, with 0.97 for the best farmer and 0.10 for the least farmer. This means that on the average, output fell by 14% from the maximum possible level due to inefficiency. About 91% of the farmers were predicted to have technical efficiency exceeding 0.70. This indicated that there are some 30% technical inefficient farmers in the study area. The result also indicates that for the average farmer in the sample to achieve technical efficiency of his most efficient counterpart, they need about 12 per cent (1 – 86.1/97.8) x 100) cost savings while the least technically efficient farmer would need 90 per cent (1 – 0.10/0.97) x 100) cost savings to became the most efficient farmer. The mean technical efficiency is similar to that reported by Maurice (2004) of 80% among cereal crop *fadama* farmers in Adamawa state in Nigeria.

Table 2: Frequency distribution of technical efficiency of watermelon farmers

Efficiency	Frequency	Percentage
0.10 – 0.49	1	0.8
0.50 – 0.59	3	2.5
0.60 – 0.69	6	5.0
0.70 – 0.79	14	11.7
0.80 – 0.89	48	40.0
0.90 – 0.99	48	40.0
Total	120	100

Elasticity of Production and Returns to Scale

The elasticity of production measures the responsiveness of output to a unit change (increase or decrease) in inputs. The aim is to estimate the degree to which the inputs considered in the model affected output. Table 3 show results of the elasticities for each input in the Cobb-Douglas stochastic frontier production function.

Table 3: Coefficients of the inputs

Factor input	**Factor Coefficient**
Seed	0.515
Farm size	0.179
Agrochemicals	0.140
Fertilizer	0.011
Labour	0.004
Farm implements	0.092
Return to scale (RTS)	**0.941**

The coefficients of the inputs reveals that seed, farm size, fertilizer and farm implements significantly explained yield at 1% levels of probabilities respectively while agrochemicals significantly explained yield at 5% level of probability. The summation of the input elasticities was 0.941, which indicates that watermelon production in the study area was in the stage II of the production surface. Stage II is the stage of decreasing positive returns to scale where resources and production were believed to be efficient. Hence, it is advisable that the production units should maintain the current level of variable input utilization but may increase the use of the fixed inputs in order to ensure maximum output, ceteris paribus.

Technical inefficiency in watermelon production

The estimates of the coefficient of the technical inefficiency model are shown in Table 4. Generally, a negative sign on a parameter means that the variable reduces technical inefficiency, while a positive sign increases technical inefficiency. The result shows that years of watermelon experience, extension contact with farmers, years of cooperative membership and amount of credit received by farmers have negative signs while age, educational level, and household size have positive signs.

The coefficient of age was 0.004, positive but not significant and therefore, decreases technical efficiency which does not agree with a prior expectation. It could be explained that since watermelon farming is less laborious compared to other food crops, age may not be a hindrance.

The coefficient of education (0.246) was positive but not significant. This indicates that the level of education attained reduce technical efficiency. This implies that high level of education is not desired for farming of watermelon and indeed, educated people opt for salaried employment in the study area. This result is in agreement with the findings of Usman (2009) among sesame farmers in jigawa state. The coefficient of household size was 0.009 positive but not significant. The positive sign indicates that the larger the family size, the greater is the technical inefficiency. This is in line with the findings of Kibaara (2005) among maize farmers in Kenya.

The negative sign on the years of farming experience variable indicates that an increase in the number of years in watermelon production, decreases farmers experience enhances technical efficiencies. This is in agreement with the findings of Egwu (2003) that years of farming experience was negative and statistically significant at 10% among rice farmers in Ebonyi state, Nigeria.

Table 4: estimates of technical inefficiency effects in watermelon production

Variables	Coefficient	Std error	t-ratios
Inefficiency model			
Constant	0.009	0.630	0.014
Age	0.004	0.007	0.561
Years of experience	-0.045	0.026	-1.720*
Educational level	0.246	0.202	1.216
Household size	0.009	0.007	1.314
Extension contact	-0.255	0.031	-8.197***
Membership of cooperative	-0.122	0.025	-4.950***
Credit	-0.037	0.020	-1.909*

***, **,* implies significant at 1%, 5% and 10% respectively

The coefficient of extension contact (-0.255), was negative and statistically significant at 1%. This agrees with the a priori expectation that extension contact is positively correlated to adoption of improved technology and techniques of production that enhances technically efficiency. This is in agreement with the works of Kudi (2005) who found out that extension contact increases productivity among sesame farmers in jigawa state.

The coefficient of years of cooperative membership is –0.122 and statistically significant at 1%, meaning it increases technically efficiency of the farmers. This is in line with the findings of Ogunyinka and Ajibefun (2003) among farmers in Ondo state. Farmers' access to credit has a coefficient of -0.037 and is statistically significant at 10%. Farmer's access to credit enhances their timely acquisition of production inputs that would enhance productivity through efficiency. This is in line with earlier result (Nwaru, 2004) among arable crop farmers in Imo State.

Hypothesis testing for Technical Inefficiency

The results of the test for the presence of technical inefficiency effects in watermelon production using generalized likelihood ratio test is shown in Table 5. The computed chi-square value for watermelon production was 95.40 and the tabulated value at 99 per cent and 11 degrees of freedom was 24.70, hence the null hypothesis that there is no technical inefficiency in watermelon production is rejected and the alternative accepted.

Table 5: Likelihood ratio tests for technical inefficiency

Null hypothesis	Calculated value	Tab value	Decision rule
No technical inefficiency	95.40***	24.72	Reject Ho

*** significant at 1%

CONCLUSION AND RECOMMENDATIONS

Watermelon farmers were found to be highly technically efficient, but have room for increasing their efficiency by 14%. To do this, it was recommended that: farm inputs such as improved seeds and agrochemicals should be made readily available and affordable to the farmers; government should demarcate and maintain proper stock routes for pastoralist to avoid encroachment into the farms and destruction of crops; and timely policies should be designed to educate farmers through agricultural extension support services.

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