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Economies of Scale and Cost Efficiency in Small Scale Maize Production: Empirical Evidence from Nigeria

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ABSTRACT This paper presents empirical study of economies of scale and cost efficiency of small scale maize production in Ondo State of Nigeria, using farm level survey data collected from 200 farms in the study area. The results shows that there is a relative presence of economies of scale among the farmers meaning that an average farm in the sampled area produce at a minimum cost considering the size of the farm which is an indication that they operates in stage II of production surface (stage of efficient utilization of resource).This result was further collaborated by the mean cost efficiency of 1.161 obtained from the data analysis which shows that an average farm in the sample area is about 16% above the frontier cost, indicating that they are relatively efficient in allocating their scarce resources. The result of the analysis indicate that presence of cost inefficiency effects in the maize production as depicted by the significant estimated gamma coefficient of about 0.81 and the generalized likelihood ratio test result obtained from the data analysis.

INTRODUCTION

Maize is a staple food of great socio-economic importance in the Sub-Saharan Africa of which Nigeria is inclusive with per capital kg/year of 40 (FAOSTAT, 2003). In Nigeria, it is the third most important cereal crop after sorghum and millet (Ojo, 2000). The total land area planted to maize in Nigeria is above 2.5 million hectares with an estimated yield of about 1.4 metric tones per hectare (Agboola and Tijani-Eniola, 1991). Ironically, the demand for maize as a result of the various domestic uses shows that a domestic demand of 3.5 million metric tones outstrips supply production of two million metric tones (Akande, 1994).

However, the unfolding performance of maize can be attributed to the fact that, bulk of the country's farm, over 90% is dependent on subsistence agriculture (small holder farmers) with rudimentary farm system, low capitalization and low yield per hectare (Olayemi, 1994). Moreover, price fluctuation, diseases and pest, poor storage facilities and efficiency of resource utilization are the identified problems of low maize production in Nigeria (Ojo, 2000). In view of this, production efficiency of small holder farms has important implications for development strategies adopted in most developing countries where the primary sector is still dominant. An improvement in the understanding of the levels of production efficiency and its relationship with a host of farm level factors can greatly aid policy makers in creating efficiency enhancing policies as well as in judging the efficacy of present and past reforms.

The Objective of this paper is to contribute towards better understanding of small scale farmers' production efficiency in Nigeria with a view of predicting allocative efficiencies (a measure of firms ability to produce at a given level of output using cost minimization input ratio) of maize farmers in Ondo State, Nigeria using stochastic frontier cost function, giving that past studies are exclusively focused on technical efficiency of farmers in Nigeria (Ajibefun et al., 2002; Ojo, 2004; Amos et al., 2004; Ogundari and Ojo, 2005).

This paper will in addition investigate factors that determine the cost efficiency of the farmers as well as determine the economies of scale of the farmers. The remainder of the paper is divided into four sections. Section 2 presents theory behind the stochastic frontier methodology. Section 3 describes the study area and the data, Section 4 discusses the result. Summary and Conclusion are discussed in section 5.

THEORY BEHIND THE STOCHASTIC FRONTIER METHODOLOGY

Theoretical Framework: Farrell (1957) distinguishes between technical and allocative efficiency (or price efficiency) as a measure of production efficiency through the use of a frontier production and cost function respectively. He defined technical efficiency as the ability of a firm to produce a given level output with a minimum quantity of inputs under certain technology and allocative efficiency as ability of a firm to choose optimal input levels for a given factor prices. In Farrell's framework, economic efficiency (EE) is an overall performance measure and is equal to the product of TE and AE (That is EE = TE*AE).

However, over the years, Farrell's methodology had been applied widely, while it undergoes many refinement and improvement. Such improvement is the development of stochastic frontier model that enables one to measure firm level efficiency using maximum likelihood estimate. The stochastic frontier model incorporates a composed error structure with a two sided symmetry and one sided component. The one sided component reflects inefficiency while the two sided component capture random effects outside the control of production unit including measurement errors and other statistical noise typical of empirical relationship.

Economic application of stochastic frontier model for efficiency analysis include Aigner *et al* (1977) in which the model was applied to U.S. agricultural data. Battese and Corra (1977) applied the technique to the pastoral zone of eastern Australia. More recently, Ogundari and Ojo (2005), Ojo (2004). Ajibefun et al. (2002), Bravo-Ureta and Pinheiro (1993) and Ali and Byerlee (1991) in which they offer a comprehensive review of the application of the stochastic frontier model in measuring of agricultural producers in developing countries.

The production technology can be represented inform of cost of function. The cost function represents the dual approach in that technology is seen as a constant towards the optimizing behavior of firms (Chambers, 1983). In the context of cost function any error of optimization is taken to translate into higher cost for the producers. However, the stochastic nature of the production frontier would still imply that the theoretical minimum cost frontier would be stochastic.

The cost function can be used to simultaneously predict both technical and allocative efficiency of a firm (Coelli, 1995). Also, it can be used to resurrect all the economically relevant information about farm level technology as it is generally positive, non-decreasing, concave, continuous and homogenous to degree one to one input prices (Chambers, 1983).

Model Specification: In this study, Battese and Coelli (1995) model was used to specify a stochastic frontier cost function with behavior inefficiency component and to estimate all parameters together in one step maximum likelihood estimation. This model is implicitly expressed as:

$$\text{In } C = g(P_i, Y_i; \alpha) + (V_i + U_i)$$

Where C_i represents the total production cost, g is a suitable functional form such as Cobb-Douglas; P_i is a vector variable of input prices (labour, fertilizer, seeds and annual depreciation cost of farm tools). Y_i is the value of maize produced in kg, á is the parameters to be estimated. The systematic component, V_i represents random disturbance costs due to factors outside the scope farmers. It is assumed to be identically and normally distributed mean zero and constant variance as N (0, σ^2v) .U_i is the one-sided disturbance form used to represent cost inefficiency and is independent of V_i. Thus, U_i=0 for a farm whose costs lie on the frontier, U_i >0 for farms whose cost is above the frontier and Ui<0 for farm identically and independently distributed as N(0,σ^2u.).The two error terms are proceeded by positive signs because inefficiencies are always assumed to increase cost.

Moreover, for the study the cost efficiency of an individual farm is defined in terms of the ratio of observed cost (C^b) to the corresponding minimum cost (C^{min}) given the available technology. That is:

Cost Efficiency (**C_{EE}**)

$$\frac{C^b}{C^{min}} = \frac{g(P_i, Yi; \alpha) + (V_i + U_i)}{g(P_i, Yi; \alpha) + (V_i)} = \exp(U_i)$$

Where the observed cost (C^b) represents the actual total production cost while the minimum cost (C^{min}) represents the frontier total production cost or least total production cost level.C_{EE} takes value of 1 or higher with 1 defining cost efficient farm. And, following the adoption of Battese and Coelli (1995) framework for the analysis of the data, the explicit Cobb-Douglas functional for the maize farms in the study area is therefore specified as follows:

$$\text{In } C = \alpha_0 + \alpha_1 \text{In}P_{1i} + \alpha_2 \text{In}P_2 i + \alpha_3 \text{In}P_3 i + \alpha_4 \text{In}P_4 i + \alpha_5 \text{In}Y_i + (V_i + U_i)$$

Where: C_i represents total production cost in naira (₦);P_1 represents cost of labour (₦);P_2 represents cost of fertilizer (₦);P_3 represents cost of seed (₦);P_4 represents annual depreciation cost of farm tools (₦) and Y_i represents output of maize in (kg). The choice of the Cobb-Douglas is based on the fact that the methodology requires that the function be self –dual as in the case of cost function in which this analysis is based on.

The inefficiency model (U_i) is defined by:

$Ui = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i}$

Where Z_1,Z_2 and Z_3 represent age, educational level and farming experience. These socio-economic variables are included in the model to indicate their possible influence on the cost efficiency of the farmers. The ás and äs are scalar parameters to be estimated. The variance of the random error, $\sigma^2 v$ and that of the cost inefficiency effects $\sigma^2 u$ and the overall variance of the model ó^2 are related as follows: $\gamma = \sigma^2 u/ \sigma^2 v + \sigma^2 u$.The gamma ($\gamma$) measures the total variation of total cost of production from the frontier cost which can be attributed to cost inefficiency (Battese and Corra, 1977). The estimate for all the parameters of the stochastic frontier cost function and the inefficiency model are simultaneously obtained using the program FRONTIER version 4.1c (Coelli, 1996).

The test for the presence of cost inefficiency using generalized likelihood-ratio statistics λ defined by: λ =-2 In (H_0/H_a)

Where:H_0 is the value of the likelihood function for the frontier model in which parameters restriction specified by the null hypothesis, H_0 are imposed; and H_a is the value of the likelihood function for general frontier model. If the null hypothesis is true then ë has approximately a mixed chi-square distribution with degree of freedom equal to the number of parameters excluded in the unrestricted model.

Economies of Scale (Es)**:* Economies of scale may be defined in terms of elasticity of cost with respect to output. However, in a multi-product setting, economies of scale (Es***) is defined as those reduction in average cost when all output are increased proportionally holding all other input prices constant. ***Es*** mathematically is equivalent to the inverse of the sum of all the elasticities of total production cost with respect to all output. Economies of scale prevail, if ***Es*** is greater than 1 and, accordingly diseconomies of scale exist if ***Es*** is below 1. In the case of Es=1 no economies of scale or diseconomies of scale exist. Return to scale and economies of scale are equivalent measures if and only if the product is homothetic (Chamber, 1988). Here, since Cobb-Douglas function was used, this assumption is imposed.

STUDY AREA AND THE DATA

Study Area: This study was based on the farm level data on small scale maize farmers in Ondo State, Nigeria. Ondo State is in the south-western part of Nigeria and lies in between longitude 4^0 30^1 and $6^0$00 east of the Greenwich Meridian and latitude 4^0 45^1 and $8^0 15^1$ north of the equator .The land area is about 13,595 square kilometre with varying physical features like hills,lowland,rivers,creeks and lagoons. The state enjoys luxuriant vegetation with vast rain forest found in the south while the Northern fringe in mostly sub-savannah forest. The people are predominantly peasant farmers cultivating mainly cash crop and food crops such as yam, cassava, maize and cocoyam for family consumption, market and cash .Farming activities are usually carried out using hand tools and other simple implements.

Sampling Technique: The data mainly from primary sources were collected from four Local Government Areas (LGAs) which were purposively selected because of prevalence of the crop in the areas using multistage sampling technique .The LGAs include Ondo east, Akure-North, Idanre and Ose LGAs. The second stage involved a simple random selection of 50 farmers from each of the four LGAs, thus making 200 respondents. Data were collected with use of a structured questionnaire to collect input-output data of the farmers defined within cost content. The output data include yield of maize in kg. The input data include cost of labour, cost of fertilizer, cost of seed and annual depreciation cost which serves as the basis of calculating total cost of production per annum. Data were also collected on the socio-economic variables such as age, years of schooling, and the farming experience of the farmers.

RESULTS AND DISCUSSION

The summary statistics of the variables for the frontier estimation is presented in Table 1. They include the sample mean and the standard deviation for each of the variables. The mean value of ₦10, 349.94 as total cost of producing 8,251.32kg of Maize per annum was obtained from the data analysis with a standard deviation of

Table 1: Summary statistics of the variables in stochastic frontier model.

Variable	*Mean*	*Standard Deviation*	*% of TC*
Total production cost (TC) ₦	10,349.94	16,289.73	
Cost of labour ₦	6,820.35	8,461.65	65.90
Cost of fertilizer ₦	1,313.84	2,864.12	12.69
Cost of seed ₦	843.60	1,084.39	8.15
Annual depreciation ₦	1,362.15	1,127.12	13.17
Maize output (kg)	8,251.32	13,731.91	
Age of farmers (years)	48.30	13.49	
Educational level (years)	11.82	8.63	
Farming experience (years)	13.60	17.18	

₦16, 289.73. The large size of the standard deviation conforms to the fact that most farms operate at different scale of operation. Analysis of cost variables of the farms shows that cost of labour accounts for about 66% of the total cost due to the fact that there is a reduction in the number of the household participation in farm operation since most farmers send their children to city for proper education . Hence, farmers depend heavily on hired labour to do most of the farming operations, thus justify the high cost expended on hired labour. Cost of fertilizer accounts for 12.6% of the total cost, cost of seed accounts for 8.2% while annual depreciation cost accounts for 13.2%.

Variable representing the demographic characteristics of the farmers employed in the analysis of the determinant of cost efficiency include; age of the farmers, educational level and farming experience. The average age of the farmers was 48.30 years meaning that the farmers were relatively young. The year of schooling was 11.82 years meaning that most of the farmers were relatively educated. The average years of farming experience was 13.60 years.

Maximum-likelihood estimates of the parameters of the stochastic cost frontier model are presented in Table 2. All parameters estimate have the expected sign with cost of labour, cost of seed, annual depreciation cost and maize output highly significant at 5% meaning that these factors were significantly different from zero and thus were important in maize production. The cost elasticities with respect to all input variables use in the production analysis are positive and imply that an increase in the cost of labour, cost of fertilizer, cost of seed, annual depreciation cost and production (maize output in kg) increases total production cost. That is 1% increase in the cost of fertilizer will increase total production cost by approximately 0.3%, 1% increase in the cost of fertilizer will increase total production cost by

Table 2: Maximum-likelihood estimates of parameters of the Cobb-Douglas frontier function for small scale maize farmers in Nigeria.

Variable	*Parameter*	*Estimate*	
General Model			
Constant	α_0	3.311	*(11.728)
Cost of labour ₦	α_1	0.258	*(6.035)
Cost of fertilizer ₦	α_2	0.054	(1.262)
Cost of seed ₦	α_3	0.143	*(3.183)
Annual depreciation cost ₦	α_4	0.072	*(2.002)
Maize output (kg)	α_5	0.482	*(8.128)
Inefficiency Model			
Constant	δ_0	-0.341	(1.285)
Age (yrs)	δ_1	-0.040	*(2.094)
Educational level (yrs)	δ_2	0.104	(1.802)
Farming experience (yrs)	δ_3	-0.008	*(2.113)
Variance Parameters			
Sigma-square	$\sigma^2 = \sigma^2 v + \sigma^2 u$	0.131	*(7.075)
Gamma	$\gamma = \sigma^2 u / \sigma^2 v + \sigma^2 u$	0.805	*(6.343)
Log likelihood function	llf	-24.18	

Figures in parameters are t-ratio
*Estimates are significant at 5% level of significance.

approximately 0.1%, 1% increase in the cost of seed will increase total production cost by approximately 0.1%, 1% increase in the annual depreciation cost will increase total production cost by approximately 0.1%, 1% increase in the maize output will increase total production cost by approximately 0.9%.However, labour cost and capital cost (cost of fertilizer, cost of seed and annual depreciation) are positive, implying that the cost function monotonically increases in input prices.

The result of the presence of economies of scale among the maize farms computed as inverse coefficient of cost elasticities with respect to the maize output in kg as the only output in the analysis shows that economies of scale prevail among the sampled farms, judging by the fact that E*s* computed is greater than one, that is ***Es*** =1.156.

The economic implication of this value is that the sample farms despite being small scale in nature expand their production capacities in order

Table 3: Generalized likelihood ratio test of hypothesis for parameters of the stochastic cost function for maize farmers in Nigeria.

Null Hypothesis	*Log likelihood*	λ	*Critical*	*Decision*
Ho:γ=o	-24.18	16.12	12.60	Rejected Ho

to decrease their cost to the lowest minimum in course of production irrespective of their size of operation which shows that the farms are experiencing decreasing but positive return to scale (stage II of production surface), since return to scale and economies of scale are equivalent measures (Chambers, 1983).This result further confirms Schultz's poor-but-efficient hypothesis that peasant farmers in traditional agricultural setting are efficient in their resource allocation behavior giving their operating circumstances (Schultz, 1964).

The estimated coefficient in the explanatory variables in the model is presented in the lower part of Table 2 for the cost inefficiency effects are of interest and have important implication. The negative coefficient for age and farming experience implies that the aged farmers and the most experienced farmers in the maize production are more cost efficient than the younger ones meaning that as the age and farming experience of farmers increases in the study area the cost inefficiency of the farmers decreases . This is in conformity with the assumption that farmers' age affects the production efficiency since farmers different ages have different levels of experience ability to obtain and process information.

The positive coefficient of year of schooling indicates that farmers' level of cost efficiency tends to decline with education. This is in contraction with the assumption that educational level of the farmers will have positive effects on the level of efficiency as they embody skill that can improve their overall efficiency.

The result of the hypothesis which specifies that the inefficiency effects are absent from the model is strongly rejected, using generalized likelihood ratio test, indicating that traditional response function (OLS) is not an adequate representation of the data. However, the result of generalized likelihood ratio test which is defined by the chi-square distribution is represented in Table 3.

The estimated gamma parameter (γ) of model 2 of 0.805 in the lower part of table 2 was highly significant at 5% level of the measurement error and other random disturbance thus indicating that about 81% of the variation in the total cost of production among the sample farmers was due to differences in their cost efficiencies.

Table 4 shows summary of cost efficiency scores for the maize farms in the sampled area. Cost efficiency is estimated as C_{EE}=exp (U_i). The mean cost efficiency of the farms was estimated as 1.161. Meaning that an average maize farm in the sample area has costs that are about 16% above the minimum defined by the frontier. In other words, 16% of their costs are wasted relative to the best practiced farms producing the same output (maize) and facing the same technology. The higher the value of C_{EE}, the more inefficient the maize farm is. However, the frequencies of occurrence of the predicted cost efficiency between 1.0 and 1.1 representing about 83% of the sampled farmers, implying that majority of the farmers are fairly efficient in producing at a given level of output using cost minimizing input ratios which reflects the farmers' tendency to minimize resource wastage associated with production process from cost perspective.

Table 4: Cost efficiencies of the sampled small scale maize farmers in Nigeria

Efficiency level	*Frequency*	*Relative Efficiency (%)*
1.0 – 1.1	165	82.5
1.2 – 1.3	27	13.5
1.4 – 1.5	4	2.0
1.6 – 1.7	2	1.0
2.0 – 2.1	1	0.5
3.0 – 3.1	1	0.5
Total	200	100
Minimum	1.043	
Maximum	3.076	
Mean	1.161	
Standard deviation	0.192	

SUMMARY AND CONCLUSION

This empirical study is on economies of scale and cost efficiency in small scale maize production using stochastic frontier cost function. A Cobb-Douglas functional form was used to impose the assumption that return to scale and economies of scale are equivalent measures if and only if the production function is homothetic. The empirical evidence indicates the existence of relative economies of scale despite the fact that the farms operate at small scale level. Relative economies of scale in the sense that, the computed overall economies of scale is slightly above one, which is an indication that the small scale maize farmers are currently expanding their present level of production, which in the long run will enable them to experience decrease in the cost of production per output. The prevailing situation is unconnected with the federal and state government of Nigeria recent public enlightenment programme to derive people back into agriculture, most especially youth in Agricultural program of Ondo State Government, which had since concentrated on maize and cassava production with relatively 1.2 hectare per farm.

Further, the outcome of this analysis shows that about 83% of the farms included in the sample operate close to the frontier level, achieving scores of about 16% or lower in terms of cost difference in the relation for the best-practiced technology. However, the level of the observed cost efficiency has been shown to be significantly influenced by age and farming experiences.

In conclusion, the relative closeness of the computed overall economies of scale (***Es***) of 1.136 and an average cost efficiency (C_{EE}) of 1.161 from unity, is an indication that although the farmers are small scale resource poor, but they are fairly efficient in the use of their resources and that any expansion in their present level of production would bring down the cost of production per output, given the prevailing but fairly economies of scale obtained for the study which is in accordance with results from earlier studies that indicate higher relative efficiency for small farms (Yotopolous and Lau, 1973; Khan and Maki,1979).

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