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Parametric Neoclassical Duality Test of Cost Efficiency in Yam (*Dioscorea sp.*) Production in Niger State, Nigeria

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Abstract—*This research presents empirical analysis of parametric neoclassical duality cost efficiency test in yam production in Niger State of Nigeria, using multi stage sampling technique to elicit farm level survey information from 80 farmers in the study area via interview schedule and validated administered pre-tested questionnaire. Parametric neoclassical duality approach (stochastic cost frontier) was used to analyze the data collected. The results reveals a relative presence of economies of scale among the farmers, implying 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 of efficient utilization of resource. This result was further collaborated by the mean cost efficiency of 1.02 obtained from the data analysis which shows that an average farm in the sample area is 2% above the frontier cost, and required 2% cost reduction to be on the frontier. Furthermore, they are efficient in allocating their scarce resources but with little cost waste. However, the depicted significant estimated gamma coefficient (54) and generalized likelihood ratio test result indicate presence of cost inefficiency effects in yam production*

Keywords: *Cost efficiency; stochastic frontier; yam farmers, Niger state; Nigeria*

1. INTRODUCTION

Yam *(Discorea species* L.) which is locally referred to as '*Doya'* in *Gbagyi/Gwari* tribe's of north central Nigeria, are starch staples in the form of large tubers produced by annual and perennial vines [11] grown in Africa, Americas', Caribbean, South Pacific and Asia. There are hundreds of wild and domesticated *Dioscorea species*, with white guinea yam (*Discorea rotundata*) been the most important species especially in the dominant yam production zone in West and Central Africa. It is indigenous to West Africa, as is the yellow yam (*Discorea cayenensis*) and water yam (*Discorea alata*), the second most cultivated species originated from Asia and is the most widely distributed species in the world.

Yams are primary agricultural commodities and major staple crops in Africa, where its cultivation began 11,000 years ago. In West Africa they are major sources of income and have high cultural value. They are used in fertility and marriage ceremonies, and a festival is held annually to celebrate its harvest.

According to [5],worldwide yam production in 2013 stood at 83 million tons, of which Africa produced 96%; majority of the world's production comes from West Africa (94%), with Nigeria alone producing 71-76% [5,7], equaling more than 58 million tons [10]. African countries imported less than 4000 tons in 2012, and exported 50000 tones, of which Nigeria accounts for 25% [10]. Worldwide annual consumption of yams is 18 million tons, with 15 million in West Africa. Annual consumption in West Africa is 61 kilograms per capita. Yams are boiled, roasted, baked or fried. In Africa they are also mashed into a sticky paste or dough after boiling.

Yam production is declining in some traditional producing areas due to declining soil fertility, increasing pest pressures and the high cost of inputs. Smallholders therefore need access to innovations to reduce cost wastage and improve productivity, given that consumer demand for yam is generally very high in this sub-region and yam cultivation is very profitable despite high production costs.

In Nigeria small scale farmers in general have been reported to be inefficient in resource use [12], given that in these studies, the efficiencies of the individual farmers were determined primarily by the use of the traditional response function technique, and making it impossible to quantify some factors that have influenced farmers' levels of efficiency using this technique. The Stochastic Frontier Analysis (SFA) developed independently, by Aigner and Meeusen and van den Broeck [1, 8] and modified by Jondrow [6] has been used in determining farm level efficiency using cross-sectional data. In this method, the cost frontier is accounted for by cost inefficiency, measurement error, statistical noise and non-systematic influences, unlike the OLS that attributes all the deviations to inefficiency [3]. The analytical method also makes it easy to ascertain policy variables that can be used to address cost inefficiency of farmers. Available literature indicates that agriculture in Nigeria is yet to benefit significantly from application of the stochastic cost frontier model in estimating cost efficiency. Therefore, the center piece 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 yam farmers in Niger State, Nigeria using stochastic cost frontier function rather than the partial vision of technical efficiency with a view to derive policy implications for proper policy recommendations.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

[4] Distinguishes between technical and allocative efficiency (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.

3. RESEARCH METHODOLOGY

The study was conducted in Niger state, Nigeria. Multi-stage sampling was used to select a total of 80 respondents from two local government areas. Pre-tested questionnaires were used to elicit informations from the farmers. Data analysis was done using stochastic cost frontier model.

Table 1.1: Sampling frame of yam farmers

Agro-zone	LGAs	Respondents
Kuta	Bosso	40
	Paikoro	40
Total	2	80

Source: Field survey, 2014

3.2.1 Empirical model

In this study, [2] 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:

$$\text{In}C=g(P_i,Y_i;\beta)+(V_i-U_i) \quad \text{.............} (1)$$

And, following the adoption of [2] framework for data analysis, the explicit Cobb-Douglas function for the yam farms in the study area is therefore specified as follows:

$$\text{In } C = \beta_0 + \beta_1\text{In}P_{1i} + \beta_2\text{In}P_{2i} + \beta_3\text{In}P_{3i} + \beta_4\text{In}P_{4i} + \beta_5\text{In}P_{5i} + \beta_6\text{In}P_{6i} + \beta_7\text{In}P_{7i} + \beta_8\text{In}Y_i + (V_i+U_i) \quad \text{........} (2)$$

Where;

C_i = Total production cost in naira (Naira);
P_1 = Cost of labour (Naira);
P_2 = Cost of fertilizer (Naira);
P_3 = Cost of yam setts (Naira);
P_4 = Cost of herbicides (Naira)
P_5 = Cost of insecticides (Naira)
P_6 = Cost of sticks-stake (Naira)
P_7 = Annual depreciation cost of farm tools (Naira); and,
Y_i = Output of yam in (kg).
β_0 = Constant co-efficient
β_{1-n}= Co-efficients of parameters to be estimated.

The inefficiency model (U_i) is defined by:

$$U_i = \delta_0 + \delta_1Z_{1i} + \delta_2Z_{2i} + \delta_3Z_{3i} + \delta_4Z_{4i} + \delta_5Z_{5i} + \delta_6Z_{6i} + \delta_7Z_{7i} + \delta_8Z_{8i} \quad \text{......} (3)$$

Where;

Z_1= Age (in years);
Z_2= Age squared (in years);
Z_3 = Education (in years);
Z_4 = Household size (in numbers);
Z_5 = Farming experience (in years);
Z_6 = Access to credit (Yes=1, otherwise= 0);
Z_7 = Extension contact (Yes=1, otherwise= 0); and,
Z_8= Soil texture (sandy loamy =1, otherwise=0).
δ_0 and δ_{1-n} are scalar parameters to be estimated.

4. RESULTS AND DISCUSSION

4.1 Summary statistics of the variables in stochastic frontier model

The summary statistics of the variables for the frontier estimation was presented in Table 1 which includes the sample mean and the standard deviation for each of the variables. The mean value of ₦ 150,675.84 as total cost of producing 4856kg of yam per annum was obtained from the data analysis with a standard deviation of ₦94, 233.25. The small size of the standard deviation justifies the fact that majority of the farms operate on the same cost scale. Analysis of cost variables of the farms shows that cost of labour accounts for 69.5% of the total cost due to the fact that large number of the household members participates in farm operation since majority of the farmers hardly send their children to qualitative educational schools due to poverty. Hence, farmers depend heavily on family labour to do most of the farming operations, thereby justify the medium cost expended on hired labour. Cost of yam setts account for 13.3%, cost of fertilizer accounts for 9.1% of the total cost, annual depreciation cost accounts for

2.2%, cost of stick-stakes accounts for 2%, and cost of insecticides accounts for 0.8%.

Variable representing the demographic characteristics of the farmers employed in the analysis of the determinant of cost efficiency include; age, education, farming experience and household size. The average age of the farmers were 42 years meaning that the farmers were relatively young and within the active productive age recommended by FAO. The year of schooling was 9.2 years meaning that the literacy level in the study area was very low, i.e hardly exceed secondary education. The average years of farming experience was 8 years, with a fairly large household size of 6 members.

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

Variables	Mean	Standard deviation	% Total cost
Total production cost (N)	150,675.84	94,233.25	
Cost of labour (N)	103,200.00	65,984.01	68.5
Cost of fertilizer (N)	14,000.00	16234.89	9.1
Cost of yam setts (N)	20,000.00	11,083.00	13.3
Cost of herbicides (N)	6000.00	7354.00	4.1
Cost of insecticides (N)	1200.00	2351.22	0.8
Cost of sticks-stakes (N)	3000.00	1653.22	2.0
Annual depreciation cost (N)	3275.83	1985.03	2.2
Yam output (kg)	4856	2467.00	
Age of farmers (years)	42	25	
Education (years)	9.2	5.21	
Farming experience (years)	8	5.6	
Household size (number)	6	9	

Source: Field survey, 2014

4.2Maximum-likelihood estimates of parameters of the Cobb-Douglas frontier function

Maximum-likelihood estimates of the parameters of the stochastic cost frontier and the inefficiency model are presented in Table 2. The diagnostic statistics for δ^2 and γ were 2.98 and 0.54, and all significant at 1 percent level, respectively. The sigma squared δ^2 indicates the goodness of fit and correctness of the distributional form assumed for the composite error term while the gamma γ indicates that the systematic influences that are un-explained by the costs function are the dominant sources of random errors, thus indicating that 54% of the variation in the total cost of production among the sampled farmers was due to differences in their cost efficiencies. Since inefficiency effects make significant contribution to the cost inefficiencies of yam farmers, thus the hypothesis which specifies that the inefficiency effects are absent from the model is strongly rejected. Furthermore, the rejection of this hypothesis was justified by using generalized likelihood ratio test which is defined by chi-square distribution which indicated that the traditional response function (OLS) is not an adequate representation of the data and the inefficiency parameters are stochastic. All parameters estimated exhibit the expected sign; costs of labour, yam-setts, herbicides, sticks-stake and yam output were highly significant at 1%, while costs of fertilizer was significant at 10%; thus these factors were significantly different from zero and were important in yam production. The costs of insecticides and annual depreciation cost of capital items was non-significant. The reason for the cost of insecticides being insignificant factor may be due to its lesser contribution to the total cost of yam production, while the non-significant of annual depreciation cost may be due to the fact that it is a sunk cost which last beyond a production cycle. The cost elasticities with respect to all input variables use in the production analysis were positive and imply that an increase in the significant variable items will increases total production cost; that is, ₦1 increase in the labour cost will increase total cost by approximately 43kobo, ₦1 increase in the cost of yam-setts will increase total cost by 2kobo, ₦1 increase in the cost of fertilizer will increase total cost by 3kobo, ₦1 increase in the cost of herbicides will increase total cost by 12kobo, ₦1 increase in the cost of sticks-stake will increase total cost by 1kobo while 1kg increase in yam output will increase total cost by approximately 41kobo. However, all costs parameters are positive, implying that the cost function monotonically increases in input prices.

The result of the presence of economies of scale among the yam farms computed as inverse coefficient of cost elasticities with respect to the yam 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*** =1.42. The economic implication of this value is that the sampled farms despite being small scale in nature expand their production capacities in order 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. 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 [13] .

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 middle-age farmers were the most experienced farmers in the yam production, and 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. For age, this findings agrees with findings of [11]; [1]; and contradicts findings of [9], while for farming experience it conforms to the findings of [11] and contradicts findings of [9]; [1]. Consistent with lifecycle effects, the coefficient of age squared had a positive effect on cost inefficiency implying that the negative association of age with cost efficiency will weaken over time. The negative coefficient of education indicates that farmers' level of cost efficiency tends to increase with education acquisition. This is in conformity 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. This finding is tandem with previous work by [9]; [11]; [1]. Access to credit had a negative coefficient, implying that farmers' who obtained credit have the opportunity of input-procurement at the appropriate time, thus, rendering them more efficient. The negative coefficient of extension contact implies that increases in extension visits lead to reduction in allocative inefficiency level. Furthermore, farmers tend to be cost efficient if the soil texture used for the production is sandy-loamy. However, the household size exhibited positive sign, which means that farmers with large family size tend to be inefficient as a result of large family expenditure been incurred.

Table 2a: Maximum-likelihood estimates of parameters of the Cobb-Douglas stochastic cost frontier function and cost inefficiency in small scale yam production in Niger state, Nigeria

Variable	Parameters	Coefficients	Standard error	t-ratios
General model				
Constant	β_0	0.2003***	0.1632	12.27
Cost of labour (N)	β_1	0.4384***	0.1122	3.91
Cost of yam-setts(N)	B_2	0.0234***	0.00159	14.74
Cost of fertilizer (N)	B_3	0.0327*	0.0191	1.7
Cost of herbicides (N)	β_4	0.1221**	0.0124	9.85
Cost of insecticides (N)	β_5	0.0215^{NS}	0.0174	1.23
Cost of sticks-stake (N)	β_6	0.0082***	0.0012	6.833
Capital Depreciation cost (N)	β_7	0.0021^{NS}	0.0016	1.313
Yam output (kg)	β_8	0.456***	0.1271	3.22
Inefficiency model				
Constant	δ_0	0.852^{**}	0.3979	2.141
Age (years)	δ_1	-0.121***	0.0214	-5.654
Age squared (years)	δ_2	0.456**	0.221	2.1
Educational level	δ_3	-0.0567**	0.0266	-2.132
Household size	δ_4	0.3122***	0.0257	12.15
Farming experience (years)	δ_5	-0.3705***	0.0448	-8.27
Access to credit	δ_6	-0.8299***	0.1073	-7.73
Extension contact	δ_7	-0.522**	0.234	-2.23
Soil texture	δ_8	-0.579*	0.3327	-1.73
Diagnostic statistic				
Sigma-square $\sigma^2 = \sigma^2v + \sigma^2u$		2.98***	0.902	3.2998
Gamma $\gamma = \sigma^2u/\sigma^2v + \sigma^2u$		0.54***	0.1992	2.71
Log-likelihood function (llf)		-11.2		
LR test		52.2		

Source: Computer print-out of FRONTIER 4.1

Note: ***,** Implies significance at 0.01 and 0.05 probability levels respectively.

Table 2b: Generalized likelihood ratio test of hypothesis for parameters of the stochastic cost function for small scale yam farmers in Niger State, Nigeria.

Null hypothesis χ^2-statistics	Log likelihood Critical value	No. of Restrictions Decision
H_0: $\gamma = 0$ 52.20	-11.20 20.27	8 Rejected

Source: Computed from MLE Result

4.3 Cost efficiencies levels of yam farmers in Niger state, Nigeria

Table 3 reveals summary of cost efficiency scores for yam farms in the sampled area. Cost efficiency was estimated as C_{EE}=exp (Ui). The mean cost efficiency estimate of the farms was 1.02. This implies that an average yam farmers in the sampled area recorded costs that is 2% above the minimum defined by the frontier. In other words, 2% of their costs are wasted relative to the best practiced farms producing the same output 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 67.5% of the sampled farmers, implying that majority of the farmers were 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. The average farmer needs a cost cut of 2% [(1 – 1.02/1)* 100] to be on the frontier, and cost cut of 1% [(1-1.02/1.01)*100] to attain the status of the most cost efficient farmer, while the poorly efficient farmer needs a cost cut of 67% [(1 – 1.67/1)* 100] to be on the frontier, and approximately cost cut of 65.4% [(1-1.67/1.01)*100] to attain the status of the most cost efficient farmer. However, the most efficient farmer needs cost cut of 1% [(1-1.01/1)*100] to be on the frontier.

Table 3: Deciles frequency distribution of cost efficiencies of yam farmers.

Efficiency level	Frequency	Relative Efficiency (%)
1.0-1.1	54	67.5
1.2-1.3	15	18.7
1.4-1.5	7	8.8
≥ 1.6	4	5
Total	80	80
Minimum	1.01	
Maximum	1.67	
Mean	1.02	

Source: Computed from MLE Results

5. SUMMARY AND CONCLUSION

This empirical study is on parametric neoclassical duality cost efficiency test in small scale yam production using parametric neoclassical 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 farmers operate at small scale level. The relative economies of scale in the sense that, the computed overall economies of scale was slightly above one, which means that the farmers were 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. Furthermore, the outcome of this analysis reveals that 67.5% of the farms included in the sample operate close to the frontier level, achieving scores of about 2% or lower in terms of cost difference relative to the best-practiced technology. However, the level of the observed cost efficiency has been shown to be significantly influenced by age, education, farming experiences, access to credit, soil texture, extension contact and household size. In conclusion, the relative closeness of the computed overall economies of scale (***Es***) of 1.42 and an average cost efficiency (C_{EE}) of 1.02 from unity, is an indication that although the farmers were above the frontier and resource poor, they are fairly efficient in the use of their resources and that any expansion in their present level of production will reduce the cost of production per output, given the prevailing economies of scale obtained for the study

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