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Technical Inefficiency in Vegetable Farms of Humid Region: An Analysis of Dry Season Farming by Urban Women in South South Zone, Nigeria

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ABSTRACT

The Stochastic production frontier function is applied to estimate output-oriented technical inefficiency of urban women cultivating waterleaf. By means of MLE, asymptotically consistent and efficient ML estimates are obtained together with inefficiency determinants. Empirical result reveals the mean level of technical inefficiency of 65%, showing that there exists scope for increasing crop production by 35% with the present technology. The result further shows the existence of constant returns to scale and positive marginal productivities of the input used. The study, therefore, recognises that growth in waterleaf output in the long run must rely on improvements in technical efficiency.

Key Words: Waterleaf production; Technical inefficiency; Stochastic function; Urban women; Nigeria

INTRODUCTION

It is widely acknowledged that the scope for agricultural production can be expanded and sustained by peasant farmers within the limits of existing resource base and available technology if farm productivity is raised by efficiency use of resources (Harwood, 1987; Ali, 1996; Udoh, 2000). This exposition therefore forms the fundamental point why the concept of farm efficiency has remained important economic study especially in developing agricultural economies, where resources are meager and opportunities for developing and adopting better technologies are dwindling (Ali & Chaudhry, 1990; Tadesse & Krishnamoorthy, 1997). Several studies pertaining to traditional agriculture are modelled to investigate input mix and the resultant output level with particular reference to input-output space with given technology. Issues of low marginal productivities, elasticities of production and high yield gap are mostly evaluated in these studies. As such, policy options nevertheless suggest progressive introduction of modern technology and new production possibilities that would see the evolution of large farms (Singh, 1992). These options however negate the premise that farmers practising traditional agriculture could be poor, but efficient in resource use. Therefore, operating on frontier due to productivity growth may not necessarily be a function of size provided that adequate technological innovations are involved. This could be the case for women in agriculture.

Though women compose between 60-80 percent of the labour force in African agriculture, (FAO, 1983), they have little access to land and resultantly plant their crops on smaller hectarage, thus the possibility for them to meet their food requirement either from production or from cash income is reduced (Udoh, 1999). Mostly the agricultural crops grown by women are termed 'minor crops' and these food crops are produced mainly for consumption especially when the main household food stocks are low (FAO, 1984; Adekanye, 1985). Apart from land, women involved in agriculture are vulnerable to different constraints. Basically, African rural women may cook for 15-16 h each day performing dual activities of maintaining their food production for family consumption with obsolete tools, and also the need for cash income needed for providing capital for both their other income-generating activities and for supplementing the meaner food supply (FAO, 1982; Udoh, 1999). In urban areas, women involvement in producing activities become even more pronounced as the need for securing a steady and independent source of cash income is very imperative. The economic reality has blurred the artificial distinction between cash and subsistence economies as most women in both rural and urban areas provide households necessities like cooking utensils, foodstuffs, toiletries etc. As such, those urban women who are not in paid jobs have resorted into part-time or full-time urban farming and petty trading. The women are more keener than men in planting vegetable crops for family consumption and cash income before devoting energy to the production of cash crops using multiple or intercropping farming system. This is the case of waterleaf (Talinum triangular) production by women in Calabar Municipality of Cross River State, Nigeria. Apart from subsistence production, many farmers (predominantly women) grow waterleaf, as a mean of income either directly in production or marketing, thus it is an economic crop in Calabar Municipality. Its production is basically small-scale using traditional manual techniques. As in the case of other vegetable crops, the women grow, market and store the crops as part of their contributions to the family income and food security.

Admittedly, waterleaf is an economic vegetable crop in the humid tropics of southeastern Nigeria that are either found in wild or in managed gardens. It is a major ingredient in much locally prepared soup and dishes the area is famous of. From a nutritional viewpoint, waterleaf has been proven to be high in Crude-protein-22.1%; Ash-33.98% and Crude-fibre-11.12%, clinically good for human consumption and also as green forage for rabbit feeding management (Ekpenyong, 1986; Aduku & Olukosi, 1990).

Evaluation of production activities of resource poor urban women is imperative in the light of resource use and productivity growth. This is an important issue of the present time, because productivity growth and resource-use efficiency issues are the core elements of sustainable crop production of small-scale farming activities. Inefficient use of inputs can jeopardise food availability and security (Udoh, 2000). This study is therefore aimed at measuring farm-level technical inefficiency effects of women vegetable farms and the determinants of inefficiency effects. Another purpose of the study is to examine resource productivities and scales of production with a view to making policy-implied statements.

Conceptual framework. The modern theory of efficiency goes back to the pioneering work of Farrell (1957) who drew extensively from the earlier works of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency, which could account for multiple inputs. Farrell identified two components of firm efficiency - technical and allocative efficiency and the combination of these two components provide a measure of total economic efficiency (overall efficiency). Technical efficiency, the main issue in this study can be measured either as input-conserving oriented technical efficiency or output - expanding oriented technical efficiency. Output-expanding oriented technical efficiency is the ratio of observed to maximum feasible output, conditional on technical and observed input usage (Jondrow *et al.*, 1982; Ali, 1996). This study however measures technical efficiency effects using output-expanding orientation.

In general, efficiency measurement has given rise to specification of various estimation methods. Kalaizandonakes *et al.* (1992) grouped these methods into two broad categories-Parametric and non-Parametric methods. For the parametric, it can be deterministic, programming and stochastic. Aigner, Lovell and Schmidt (1977), and Meeusen and Van den Broek (1977) independently proposed the idea of stochastic measurement. The specification of stochastic parametric frontier recognise component error term as major source of deviation from production frontier. By definition, stochastic frontier production function is

$$Y_i = F(X_i; \beta) \exp(V_i - U_i) \quad i = 1, 2, ..., N \qquad (1)$$

Where Y_i is the output of ith firm; X_i is the corresponding (M x 2) vector of inputs; β is a vector of unknown parameter to be estimated; F(.) denotes an appropriate functional farm, V_i is the symmetric error component that accounts for random effects and exogenous shock; while $U_i \leq 0$ is a one sided error component that measures technical inefficiency.

The major interest in efficiency study that specifies stochastic frontier is the decomposition of the component error terms (V_i-U_i) into mutually exclusive events. This is normally accomplished by estimating the mean of conditional distribution of U given V expressed as:

$$E(U/e_i) = \mu_i + \sigma^* \{f^*(-\mu_i/\sigma^*)[1-F(\mu_i/\sigma^*)]^{-1}\} \qquad (2)$$

Where $\sigma^* = (\sigma_v^2\ \sigma_u^2/\sigma^2)^{1/2}$; $\mu = (-\sigma_u^2 e_i)/\sigma^2$ and f is the standard density function and F is the standard distribution function. Given functional and distributional assumptions, the values of unknown coefficients in equation (1) and (2) can be obtained jointly using the maximum likelihood (ML) method. This involves estimation of population parameters such that the probability density for obtaining the actual sample observations that have been obtained from the population is greater than the probability density obtainable with any other assumed values (estimates) of the population parameters (Draper & Smith, 1966; Stevenson, 1980; Coelli, 1995; Olayemi, 1998). The ML method provides estimators that are asymptotically consistent and efficient.

In the recent years, econometrics modelling of stochastic frontier methodology associated with efficiency estimation has been important area of economic research. These studies estimate individual firm efficiency levels with both time varying and cross sectional data. The studies are mostly based on Cobb-Douglas function and transcendental logarithmic functions that are specified either as production function or Cost function (see Battese & Corra, 1977; Kalirajan, 1981; Bagi & Hunag, 1983; Bagi, 1984; Kumbhakar, 1994; Ali, 1996; Apeziteguia & Garate, 1997; Yao & Liu, 1998; Reinhard *et al.*, 1999). Obviously, for all these studies, farm level technical efficiency effects ranged from 0.20 to 0.98. In Nigeria, however, the use of stochastic frontier to estimate farm level efficiency effects is still at rudimentary level and is beginning to build up. Few studies have been undertaken, but there is still dearth need for more empirical studies on this important issue.

Therefore, this study uses a production approach to estimate technical inefficiency effects at farm levels by assuming a stochastic nature of production.

METHODOLOGY

The study area, sampling and data collection procedure. The study was carried out in Calabar Municipality, the capital city of Cross River State, Nigeria. It has a total landmass of 1480 sq km with estimated population of 320,862 of which 166203 and 154659 are male and female respectively (1991 NPC). The area falls within the humid tropics with two distinctive seasons-dry and wet seasons and falls within the humid tropics with two distinctive seasons dry and wet seasons. The occupation of the residents reflects the economic reality of the city. With its status as administrative city, many government workers reside here. Minimum commercial activities are also carried out. However, to complement sources of family income, some individuals are involved in urban farming activities, especially women. This primarily centers on the production of vegetables in home gardens in which waterleaf cultivation features prominently.

Data used in the study are primary data collected directly from the farmers with the use of structural questionnaires during dry season of 2000/2001 planting period. Production of waterleaf is at peak during dry season. A total of 320 farmers were randomly sampled from areas of intensive waterleaf cultivation. The baseline survey covers information on input use, management practices, output level and other socio-economic information.

The empirical model. The study utilised stochastic production frontier, which builds hypothesised efficiency determinants into the inefficiency error components (Battese & Coelli, 1995 and Shujie & Liu, 1996). Assuming a Cobb-Douglas functional form given as

$$\mathrm{Ln}(\mathrm{Qty}_i) = \beta_o + \beta_1 \ln(\mathrm{Land}) + \beta_2 \ln(\mathrm{Labour}) + \beta_3 \ln(\mathrm{Water}) + \beta_4 \ln(\mathrm{Manure}) + \beta_5 \ln(\mathrm{Fertilizer}) + \beta_6 \ln(\mathrm{Plant\ material}) + \beta_7 \ln(\mathrm{Capital}) + V_i + U_i \quad (3)$$

With $Vi \sim N(0,\sigma_v^2)$; and

$$e^{-ui} = P_o + P_1(\mathrm{EDU}) + P_2(\mathrm{Age}) + P_3(\mathrm{EXP}) + Z_i \quad (4)$$

Where EDU is the education (years), Age is age of the farmer (years), EXP is the experience (in years) and Z_i is an error term assumed to be randomly and normally distributed.

Empirical Results and Interpretations

ML estimates results. The model specified is estimated by the ML method using a computer programme FRONTIER 4.1 developed by Coelli (1994). The ML estimates are presented in Table I.

Table I shows ML estimates and inefficiency determinants of the specified frontier. The sigma square (0.0224) is statistically significant and different from zero at $\alpha = 0.01$. This indicates a good fit and the correctness of the specified distributed assumption of the composite error term. The variance ratio, defined as $\lambda = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$ is estimated to be as high as 94.72%. This suggests that systematic influences that are unexplained by the production function are the dominant source of random errors. In other words, the presence of technical inefficiency among the sample waterleaf gardens explains about 94.72% variation in the output level of the crop grown.

This therefore confirms the presence of one-sided error component in the specified model, thus a classical regression model of Production function based on ordinary least square estimation would be inadequate representation of the data. The generalised likelihood ratio test ($\chi^2_{(7)} = 9.6484$) is highly significant. This also suggests the presence of the one - sided error component. Therefore, the results of the diagnosis statistics confirm the relevance of stochastic parametric production function and maximum likelihood estimation.

The production function estimates indicate the relative importance of factor inputs in waterleaf production. Except for fertilizer use and capital, the coefficients of other factors have the expected signs and magnitudes. Manure appears to be the most important factor of production with an elasticity of 0.4057; being consistent with the observation that majority of the women boast and maintain output level of waterleaf with application of farmyards manure, mainly poultry droppings. The policy implication is that it is imperative for the government to create enabling environment for the striving of poultry farms and encouragement of organic manuring of other crop farms through adequate extension services. Continuous use of organic manure would not only increase crop productivity, but would go a long way in augmenting land and repairing damaged tropical soils.

Water appears as the second most important factor, with an elasticity of 0.2354, followed by planting material input, with an elasticity of 0.1472. Land and labour are also important factors that determine output level of waterleaf. The relative importance of water for waterleaf production cannot be over emphasised considering that irrigation is a major land - augmenting input that improve the quality of existing land by raising yield per hectare. Also, decomposition and mineralisation of FYM requires sufficient water supply so that the major elements are released to the growing crops. Waterleaf farmers as they engage in production during dry seasons need sufficient water for irrigation of their waterleaf gardens.

Inorganic fertilizer is used mostly as complementary land- augmenting inputs to organic manure. This reason explains why its coefficient bears wrong sign and is statistically not significant. Also, the insignificance of capital input coefficient further explains the labour intensive nature of waterleaf production with limited use of crude tools. The result of production function estimates is quite revealing and adequate to explain the descriptive statistics pertaining to the sample characteristics of the variables examined as presented in Table II.

The estimated coefficients of the inefficiency function provide some explanations for the relative technical efficiency levels among individual farms. The coefficients of the inefficiency variables are highly significant, except the coefficient of age. It therefore follows that both educational levels of the women and their experiences in waterleaf production positively affect the farm level technical efficiency effects. These results are quite plausible: more years of education enables farmers to acquire and process relevant information more effectively; and also specialisation is developed via experience which eventually lead to improved method of production, hence higher level of technical efficiency. This result agrees with the findings of Haffman (1977), Ram (1980) and Parikh *et al.* (1996).

Resource-use inefficiency. Farm-specific resource-use inefficiency indices are shown in Table III.

From both Table III and Fig. 1, the frequency distribution of inefficiency shows a sharp rise and fall from left to right at different intervals with modal class not falling into any of the extreme classes. Therefore, the occurrence of the mode of distribution, 0.442 (44.28%) supports the use of more general distribution (than the often considered half-normal distribution or exponential distribution) for inefficiency effects. The assumption of a generally truncated-normal distribution for inefficiency effect ($-U_i$) is therefore justified.

The average resource - use inefficiency in the sample is 0.3487 (34.87%) leaving efficiency gap of 0.6513 (65.13%). This implies that about 34.87% higher production could be achieved without additional resource, or input use could be reduced to achieve the same output level. From the distribution, the most efficient farmer in terms of resource use have index of 60.94% (maximum value of inefficiency index of 30.06%) and the least efficient ones have resource use efficiency of 15.38% (maximum value of inefficiency index of 84.62%).

The rather low degree of technical inefficiency suggests that very little marketable waterleaf output is sacrificed to resource waste. But the inability of any of the waterleaf farmers to operate on the frontier could be attributed to certain factors ranging from technical production constraint, socioeconomic factors and environmental factors. Specifically, scare inputs may be allocated to various users on the basis of their marginal shadow values thereby preventing the farmers from reaching the efficiency frontier. However, the distribution of the inefficiency estimates agree with previous works carried out in other peasant farming settings (see Ali & Byerlee, 1991; Parikh *et al*., 1995; Coelli & Battesse, 1996).

Relationship between inefficiency indices, farm size and output level. The extent to which farm size and output level relates to the farm-specific technical inefficiency indices is presented in Table IV.

As shown in Table IV, inefficiency effects have inverse and linear relationships with output levels, but undefined relationship with farm size. As such lower inefficiency index corresponds with greater output level and vice versa.

This linear relationship therefore supports the estimation of the technical inefficiencies terms by output-expanding orientation technique; the ratio of observed to maximum feasible output, conditional on technology and observed input usage. The result therefore confirms the thesis that efficient use of resources enhances increase in output level of farm produces, which ensures productivity growth. This however is a major aspect of sustainability.

The undefined nature of relationship between inefficiency effects and farm size seemingly point to the fact that farm size may not have direct influence on how farmers use other resources. The influence could only be noticeable where the soil quality and fertility significantly differs. However, one obvious thing among the sampled gardens is that none of the farmers has farm size up to one hectare, but with average farm size of 0.033 ha, their farms are generally small.

Table I. ML Estimates and Inefficiency Function

Variables	Coefficients	Asymptotic t – value
Production Function		
Constant term (β_o)	8.4251	8.5005
Land (β_1)	0.1340	2.7303
Labour (β_2)	0.1028	1.9013
Planting material (β_3)	0.1472	4.7554
Manure (β_4)	0.4057	3.7519
Fertilizer (β_5)	-0.0504	-1.0377
Water (β_6)	0.2354	2.1319
Capital (B_7)	0.0294	0.3945
Inefficiency Function		
Intercept (P_o)	1.0091	2.0626
Education (P_1)	-0.0320	-1.8507
Age (P_2)	0.3295	0.2548
Experience (P_3)	-0.1576	-2.5129
Diagnosis Statistics		
Sigma - square (δ_s^2)	0.0224	4.4754
Gamma (λ)	0.9472	3.3210
L n (Likelihood)	19.2093	
LR test	9.6484	
Quasi-function	1.0041	
Number of observations	320	

Note: All explanatory variables are in natural logarithms. A negative sign of the parameter in the inefficiency function means that the associated variable has a positive effect on technical efficiency, and a positive sign indicates the reverse is true

Source: Computer printout of Frontier 4.1

Table II. Mean Values of Output and Explanatory Variables

Description	Unit	Mean value	Min. Value	Max. Value
Output	Kg	2366.18	215.14	7768.98
Labour	Mandays	13.037	1.16	36.8
Land	Hectares	0.0329	0.001	0.22
Water	Liters	4435	107.68	8601
Fertilizer	Kg	9.17	1	50
Manure	Kg	111.275	1	200
Planting material	Kg	174.44	23.9	517.93
Capital	N:K	18.18	12.05	28.00
Education	Years	6.15	1	11
Experience	Years	5.15	1	10
Age	Years	43.37	25	68

Source: Field Survey 2000/2001

Resource productivities and scales of production. Considering the nature of elasticities of the factors of production and the quasi function of 1.0041, the returns to scale for input use are constant, as the sum of factor elasticities does not differ significantly from unity. The presence of constant return to scale may be caused by the use of labour intensive simple technology in waterleaf production by the women. This practise however does not increase the productivity of labour and other complementary inputs when capital input is increased. That is, the benefits

Fig. 1. Distribution of inefficiency indices in waterleaf farms

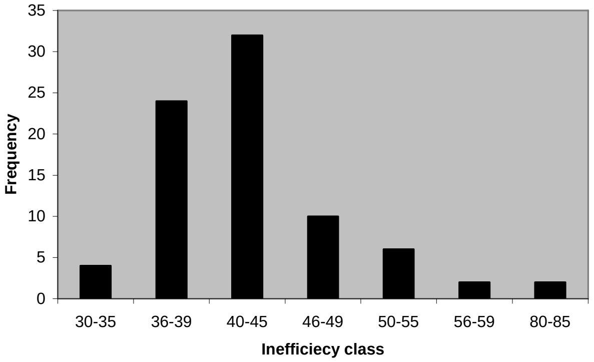

Table III. Distribution of Farm - specific Technical Inefficiency Indices among waterleaf farmers

Inefficiency class (%)	Frequency	Percentage
30 – 35	4	5
36 – 39	24	30
40 – 45	32	40
46 – 49	10	12.5
50 – 55	6	7.5
56 – 59	2	2.5
80 – 85	2	2.5

Mean value = 34.87
Mode value = 44.23
Minimum value = 30.06
Maximum value = 84.62
Skewedness = 2.7827
Kurtosis = 12.5433
Source: Frontier 4.1 Result.

of technical economies of scale may not be realised. Instead, a doubling of capital inputs, for instance requires a corresponding doubling of labour and other complementary inputs, including farmland, and this gives rise to a doubling of output.

The estimation of input productivities of the on the basis of elasticities of production indicates positive and high marginal physical productivities and marginal value products of all the conventional inputs, except capital. This is an indication of appreciable economic returns to the waterleaf farmers on their inputs less as shown on Table V.

The presence of constant returns to scale marks the point of long-run production equilibrium where total output of waterleaf produced by the urban women is just exhausted as each factor of production receives its marginal product. As the long-run production equilibrium exists, then the farmers are operating at Stage II of production process. This is a point where the quotient of average cost and marginal cost is unity.

CONCLUSION AND RECOMMENDATIONS

In this study, the central issue was the use of survey data on inputs and aggregate waterleaf output by urban women to measure farm-level technical inefficiency terms through Stochastic parametric estimation method. Cobb-Douglas production frontier was estimated by maximum likelihood estimation to obtain ML estimates and inefficiency determinants. The parameters obtained were asymptotically efficient and consistent. The diagnostic statistics confirmed relevance of Stochastic function and maximum likelihood estimation; presence of one sided error component which is generally truncated in distribution; and that a classical regression model of production based on ordinary least square estimation would be inadequate representation of the data.

Table IV. Distribution of Farm-level Technical inefficiency indices, Average Farm size and output level

Inefficiency Class (%)	Average farm size (ha)	Output level (kg)
30-35	0.02	3420.98
36-39	0.035	2912.35
40-45	0.0427	2935.88
46-49	0.0107	2031.87
50-55	0.043	2012.43
56-59	0.0166	1542.68
80-85	0.0122	301.79

Source: Field Survey 2000/2001

Table V. Marginal Physical Products and Marginal Value Products

Inputs	MPP (Kg)	VMP (N.K)
Land (ha)	9.63	44.01
Labour (mandays)	18.66	85.27
Manure (kg)	8.63	39.43
Fertilizer (kg)	-13.00	-59.41
Planting Material (kg)	3.19	14.58
Capital (N.K)	3.83	17.50
Water (liter)	0.078	0.35

Note that 1kg of waterleaf sold for N4.57 as of 2000/2001-farm gate price.
Source: Field Survey 2000/2001

The study revealed existence of constant returns to scale on the input used, but positive and high marginal productivities in physical and value terms.

The overall average technical inefficiency term of 34-87% showed that the waterleaf farmers could increased the scope of their production to narrow the existing gap and increase input use productivity. As determinants of efficiency, education and experience had positive impacts on efficient use of resources in waterleaf production.

In line with the findings of the study, the following recommendations are made:

- ♦ To derive the benefit of economies of scale, farm size should be increased and farmers should use more manure then inorganic fertilizer as it is relatively cheaper and also have higher net return
- ♦ Provision of adequate extension and supportive services by government with a view to advising the women better ways of cultivating waterleaf

- There is need for adoption of capital augmenting technology to replace the simple tools
- There is also need for consolidation of farm lands as this will encourage mechanisation as well as give the women better access to credit as a group

In conclusion, therefore, raising productivity of waterleaf farmers in line with tenet of economic theory, the biophysical potentials and the production possibility limits within the paradigm of sustainability are considered as foundations for development of peasant agriculture. This is also the case for the urban women who eke out living on cultivation of waterleaf.

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