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Technical Efficiency and its Determinants in Garden Egg (*Solanum Spp*) Production In Uyo Metropolis, Akwa Ibom State, Nigeria

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Abstract. The study analyzed the technical efficiency and its determinants in garden egg production in Uyo metropolis using stochastic frontier analysis. A cost route approach was adopted in eliciting information from 90 garden egg farmers selected through simple random sampling techniques. The results show that all the production variables analyzed were positive and statistically significant except capital. The implication is that the production function was an increasing function. The major determinants of efficiency were identified to be farm size and gender. Smaller farms were found to be more efficient than larger ones. This further supports Schultz's (1964) hypothesis that small farms in developing countries are poor but efficient, and Mkhabela's (2005) observation that small farmers are more efficient than large ones. In addition, men were found to be less technically efficient than women, perhaps also because women generally control smaller farm size than men. The results further revealed that the farmers were not very technically efficient, with a mean efficiency of 0.86. The mean efficiency could therefore be improved by 14% through better use of available resources. These observations suggest that providing an enabling environment for urban smallholder farmers and perhaps resource rationalization between men and women could enhance their productivity and hence help in reducing urban poverty.

Keywords. Productivity, Technical efficiency, Stochastic frontier, Garden-egg production, Nigeria.

1 Introduction

In recent years, urbanization has led to an increasing loss of agricultural land, thus reducing the agricultural growth rate in sub-Saharan Africa and Nigeria in particular. Urbanization presents both challenges and opportunities for the developing countries as a whole. There is an indication that the challenges of urbanization out-weigh its opportunities in these regions. This may be because urbanization has not yet been matched with infrastructural and economic development. This in turn leads to urban poverty and food insecurity (Cleave 1974).

Recent data have shown that the highest urban growth rates are in the developing countries. In Nigeria it is 5.3% a year, the fastest in the World (Fontem and Schippers 2004). Today 47% of the world's population lives in urban areas and by 2015, the urban population will rise to 53% (Nugent 2000). Consequently, many city dwellers will be faced with the reality of unemployment, and inadequate food and shelter; and they are powerless to influence the decisions affecting these issues, all of which are dimensions of poverty, with hunger as the most fundamental (Umoh 2006).

Urban Agriculture (UA), which is the growing of crops and raising of animals within and around cities (Cleave 1974), has emerged as a strategic imperative for developing countries (Armar-Klemesu and Maxwell 2000). UA is not a new or recent invention. Agricultural activities within city limits have existed since the first urban populations were established thousands of years ago (Drakakis-Smith 1997). However, it is only recently that UA became a special focus of research and development, as its scale and importance in an urbanizing world become increasingly recognized (Lynch *et al*. 2001). This is essentially due to its potential for poverty reduction, economic empowerment, and household food security.

It is estimated that 800 million people are engaged in UA worldwide, of which 200 million are considered to be market producers, employing 150 million people fulltime (RUAF Foundation 2007, Enete and Achike 2008). These urban farmers produce substantial amounts of food for urban consumers. In Accra, 90% of the city's fresh vegetable consumption is from production within the city (Fontem and Schippers 2004). There is every indication that a sizeable number of the urban poor are engaged in UA (Drescher 2002).

As the population of the urban poor practicing agriculture increases, there is an increased competition for the few, available plots of urban land. This could increase the risk associated with UA as urban structures could come without notice and midway into a planting season, thereby destroying the crops planted. In addition, there is also the risk of low investment and hence low productivity of UA because of under capitalization of the poor who are practicing UA.

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Several studies have been carried out on UA in Africa (Parikh and Shah 1995, Adewumi 2008, Arene and Mbata 2008, Fasasi 2006). All these studies concluded that it has the potential to reduce poverty, improve food security and generate employment. However, there is a large gap between supply and demand of food given the increasing poverty in urban areas, especially consumption poverty. To achieve the Millennium Development Goal of halving the proportion of hungry people by 2015, it is projected that 22 million people must attain food security every year. This could achieved only if the available resources are efficiently utilized. This is because the urban food production problem has been heightened by the relatively low level of productivity of the resources used by the farmers (Ojo, 2004). In order to enhance the productive capacity of the farmers, knowledge of the availability of the aggregate farm level resources and differences in their productivities is essential. Therefore, the study of their present level of efficiency and the analysis of the factors influencing their level of efficiency is necessary. This will indicate the possibility of increasing their productivity level by highlighting the direction of resource use adjustment and allocation (Ogandari and Ojo, 2007).

The term efficiency of a firm can be defined as its ability to produce the largest possible amount of output from a given set of inputs. The modern theory of efficiency dates back to the pioneering work of Farrel (1957) who proposed that the technical efficiency of a firm consist of technical and allocative components, and the combination of these two components provide a measure of total economic or overall efficiency. Technical efficiency, which is the main focus of this study, is the ability to produce a given level of output with a minimum quantity of inputs and 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 (Ali, 1996).

The term frontier involves the concept of maximality in which the function sets a limit to the range of possible observations (Forsund et. al, 1980). Thus it is possible to observe points below the production frontier for firms producing less than the maximum possible output, but no point can lie above the production frontier given the technology available. The frontier represents an efficient technology, and deviation from the frontier is regarded as inefficient. An economically efficient input–output combination will be on both the frontier function and the expansion path.

Vegetables (leafy and fruits) are widely grown in most parts of Sub-Saharan Africa, especially in the urban areas, and they constitute the most affordable and sustainable source of micronutrients in diets. They provide between 30% and 50% of iron and vitamins in resource poor diets (Sabo and Dia, 2009).

Garden egg (*Solanum spp*) is a vegetable with increasing popularity in the world (Pessarakli and Dris, 2003), and it originated from tropical Africa (Norman, 1992). It is an economic flowering plant belonging to the family *Solanaceae*, whose members are mostly herbaceous plants. The fruit is berry; the seeds have large endosperm, and are grown mainly for food and medicinal purposes. Nutritionally, garden egg contains water (92.5%), protein (1%), fat (0.3%), and carbohydrates (6%). Medicinally, a meal of garden egg has been proven to benefit patients suffering from raised intraocular pressure (glaucoma) and convergence insufficiency, as well as in heart diseases and arteriosclerosis (Guardian, 2009). The crop is widely cultivated across most of the African continent, and more intensively in West and East Africa. It is consumed almost on a daily basis by urban families and also represents the main source of income for producing households in the forest zones of West Africa (Danquah-Jones, 2000).

Despite the local importance of garden egg in the study area, several farm-level efficiency studies on vegetable production focused on waterleaf and fluted pumpkin (Idiong *et al*.(2002), Umoh, 2006; Udoh and Etim, 2006; Udoh and Etim, 2008). There has been limited information on garden egg production in the study area. This study therefore aims at estimating technical efficiency and its determinants among urban garden egg farmers in the area. This, it is hoped, will help to enhance their efficiency and productivity and hence improve their income and reduce urban poverty.

2 Materials and methods

The Study Area: The study was conducted in Uyo metropolis, the capital of Akwa Ibom State, Nigeria. Uyo is situated 55 km inland from the coastal plain of south Eastern Nigeria. The area lies within the humid tropical rainforest zone with two distinct seasons, the wet and dry season. The annual precipitation ranges from 2000-3000 mm per annum. The area is located between latitude $5^0 17^1$ and $5^0 27^1$ N and longitude $7^0 27^1$ and $7^0 58^1$ E and covers an area of approximately 35 square kilometers. Uyo is a fast-evolving metropolis with considerable governmental, civil and commercial activities and rich potential for agriculture. The inhabitants of Uyo engage in part-time farming as a way of augmenting and supplementing family income and food supplies (Etim *et al*, 2006). The majority of the farmers are small-scale farmers with an average farm size of about one hectare. Farming practices involve the use of hand tools and other simple implements. The crops widely grown in the area include yam, maize, cassava, plantain, cocoyam and vegetables such as waterleaf, fluted pumpkin and garden egg.

3 Sampling procedure and data collection

The metropolis, especially the area where garden egg farming occurs, is mainly populated by two clans – the *Offots* and *Okus*. Through the assistance of the local council department of agriculture, the list of garden egg farmers in the two clans within the metropolis was obtained. Fourty-five farmers were then randomly selected from each clan to make a total of 90 farmers for the study. Data for the study were mainly primary data collected from the farmers during the 2008/2009 planting season with the use of a structured questionnaire. This was done through the cost route approach. Information was collected on input use, output level and socio-economic characteristics.

4 Method of data analysis

The data collected were analyzed using descriptive statistics (mean, standard deviation) as well as the stochastic production

Table 1. Summary statistics of output and explanatory variables

Description	Unit	Mean value	Std.Deviation	Max. value	Min. value
Output	Kg	890.82	160.58	1460	534
Labour	Mandays	218.86	72.78	492	125
Land	Hectares	0.27	0.17	0.75	0.04
Fertilizer(inorganic)	Kg	11.77	5.92	30	0
Manure(poultry)	Kg	97.44	47.51	225	25
Planting material	Naira	909.33	608.66	2500	150
Capital	Naira	1804	595.38	3655	918
Household size	Number	5.81	2.02	11	2
Experience	Years	8.71	5.85	36	3
Education	Years	7.44	3.72	16	0
Age	Years	43.73	8.31	65	28

Source: field survey, 2009.

frontier, which builds hypothesized efficiency determinant into the inefficiency error components (Coelli and Battese, 1996). The production technology of the farmers was assumed to be specified by the Cobb-Douglas frontier production function which is defined by:

$$Ln(QTY)= \beta_0 + \beta_1 Ln(land) + \beta_2 Ln(labour) + \beta_3 Ln(fert.) + \beta_4 Ln(manure) + \beta_5 Ln(p.mat) + \beta_6 Ln(capital) + vi - \mu i \quad (1)$$

Where Ln denotes logarithms to base e, QTY is the quantity of garden egg harvested in kg; land is the land size measured in hectares; labour is the labour employed in farm operations measured in man-days per hectare; fert. is the inorganic fertilizer applied in the farm measured in kg; manure is the poultry manure applied in the farm, measured in kg; p.mat is the value of planting material measured in Nigerian Naira; capital is the depreciated value of farming equipment measured in Nigerian Naira; and vi = random error assumed to be independent of μi, identical and normally distributed with zero mean and constant variance $N(0,\partial^2)$; μi = technical inefficiency effects which are assumed to be independent of vi, non-negatively truncated at zero and distributed - $N(u,\partial^2)$. If $\mu i < 0$, no inefficiency occurs, the production lies on the frontier. If $\mu i > 0$, the production lies below the frontier and it is inefficient.

4.1 Efficiency Model

In addition to the general production model, the efficiency model was defined to estimate the influence of socio-economic variables on the technical efficiencies of the garden egg farmers. The model is defined by:

$$\mu i = b_0 + \partial_1 x_1 + \partial_2 x_2 + \partial_3 x_3 + \partial_4 x_4 + \partial_5 x_5 + \partial_6 x_6 \quad (2)$$

Where

μi is as defined before

x_1 = level of education attainment of the farmer in years

x_2 = household size

x_3 = age of the farmer in years

x_4 = farming experience in years

x_5 = farm size measured in hectares

x_6 = gender of a farmer (dummy: 1 if female, 0 otherwise)

∂'s, β's and γ coefficients are unknown parameters to be estimated along with various parameters which are expressed in terms of $\partial^2 - \partial v^2 + \partial u^2$, γ(gamma) $\partial u^2 / \partial^2$ where the γ- parameter has a value between zero and one ($0 \leq \gamma < 1$)

5 Results and discussion

The summary statistics of the variables used for the stochastic frontier production function is presented in Table 1 above. Average output per farmer per production cycle is 890.82 kg while the analysis of inputs revealed an average farm size of 0.27 ha per farmer, an indication that the study covered small-scale family-managed farm units. The average labour used of 218.86 man days per hectare shows that garden egg farmers depend heavily on human labour to do most of the farming operations. With relatively available cheap labour in Nigeria, extensive use of human labour for farming has been shown to make vegetable farming, especially in the urban areas, profitable (example is Enete and Okon 2008). The summary further revealed that garden egg farmers were experienced (8.71 years) and educated with about 7.44 years of schooling. Both experience and education could equip the farmers with relevant skills for enhanced farm management and hence productivity. The farmers were young as indicated by a mean age of 43 years.

The maximum likelihood (ML) estimates of the parameters of the stochastic production frontier were obtained using the

Table 2. Maximum likelihood estimation of the Cobb-Stochastic production function

Production factors	Parameters	Coefficient	Standard error	T-value
Constant term	β_0	2.7165	0.4602	5.9035***
Land size (x_1)	β_1	0.4788	0.1078	4.4383***
Labour (x_2)	β_2	0.1583	0.0620	2.5526**
Fertilizer (x_3)	β_3	0.0558	0.0277	2.5389**
Manure (x_4)	β_4	0.0454	0.0089	5.0766***
Planting material (x_5)	β_5	0.3224	0.0852	3.7862***
Capital (x_6)	β_6	0.0824	0.0831	0.9921
Efficiency factors				
Constant term	d'_0	6.4129	5.2620	1.2187
Educational level (∂_1)	d'_1	0.4715	0.4136	1.1399
House size (∂_2)	d'_2	1.1289	0.9772	1.1399
Age (∂_3)	d'_3	-1.8138	1.6569	-1.0947
Experience (∂_4)	d'_4	0.2475	0.3324	0.7446
Farm size (∂_5)	d'_5	-0.9461	0.4371	-2.5710**
Gender (∂_6)	d'_6	-0.0052	0.0947	-5.5419***
Variance parameters				
Sigma squared	$o^2 = o^2v + o^2v$	.90488		
Gamma	$\gamma = o^2v / o^2$	9.1606		
Log likelihood function		60.7648		
LR test		21.9582		
No. of observations	90			

Source: computer printout of FRONTIER 4.1c, using field survey data, 2008/2009.
Note: *** = significant at 1%, ** = significant at 5% level of probability.

program, FRONTIER 4.1c (coelli, 1995). The result is presented in Table 2 above.

The sigma squared (0.9048) is statistically significant and different from zero at $\alpha = 0.01$. This indicates a good fit and the correctness of the distributional form assumed for the composite error term. The variance ratio, known as gamma (γ) = 9.16, indicates that systematic influences that are unexplained by the production function are the dominant sources of random error. This means that 91.6% of the variation in output among the garden egg farmers was due to disparities in technical efficiency. The presence of one sided error components in the specified model is thus confirmed, implying that ordinary least square estimations would have provided an inadequate representation of the data. The generalized likelihood ratio test ($\lambda^2 = 0.2195$) is significant. The result of the judgment statistics does confirm that the stochastic frontier model appears to be a significant improvement over an average (OLS) production function.

The estimated ML coefficients of all the variables in the production function were all positive and conformed with the *a priori* expectation, indicating that the estimated production function is an increasing function. The coefficient of land size was positive and significant with a production elasticity value of 0.158. Therefore, a 10% increment in land size will increase output of garden egg by 1.58%. This means that there is scope for increasing output by expanding farmland. The coefficient of labour was positive and significant at a 5% level of probability, showing the importance of labour in garden egg production in the area. This might be because all agronomic practices involved in garden egg production are done manually with hand tools (hoe and matchet), thus confirming the labour intensity of the crop. Several other studies (Umoh, 2006; Okezie and Okoye, 2006; Udoh and Etim, 2008) also had similar findings. The production elasticity value of output with respect to quantity of fertilizer applied was 0.5584. The coefficient was statistically significant at 5% probability level. This means that if the quantity of fertilizer was increased by 10%, output will be improved by a margin of 5.584%. The vegetative nature of garden eggs should make its output heavily dependent on soil fertility, and under intensive agriculture, soil fertility maintenance is very crucial for sustenance. The coefficient of manure was positive and significant at a 1% level of probability. The production elasticity of manure (0.4543) shows that if the quantity of manure was increased by 10%, output will be increased by 4.5%. The farmers usually augment their inorganic fertilizer application with that of poultry manure, which is usually cheaper and environmentally friendlier. The estimated ML coefficient for planting material was positive and significant at 1%. Planting material here is the value (in Nigerian Naira) of garden egg seeds used per hectare, and everything being equal, the higher the value, the higher the number used. This could translate to a higher density of garden egg plants per hectare and perhaps a higher output. This finding is similar to those of Ajibefun , Battese, and Daramola (2002) and Udoh (2006). The coefficient of Capital was positive but not significant. This further explains the low external input (LEI) production status of garden eggs in the study area.

In the efficiency model, educational level, household size, and farming experience were all positive but not statistically significant. The age of the farmer had a negative coefficient but was also not significant. Farm size was, however, negative and significant in the efficiency model. This suggests that smaller farms are more efficient than larger farms. Considering the small scale nature of garden egg production in the area, this result further supports Schultz's (1964) hypothesis that small farm households in developing countries are "poor but efficient". Also, Mkhabela (2005), in comparing the efficiency level between small and large scale farmers, noted that small scale farmers (those who have below 1 ha of vegetable farm) were more efficient than large scale farmers (those who have above 1 ha of vegetable farm). The coefficient of gender was negative and statistically significant at a 1% level of probability. This suggests that men were less technically efficient than women in garden egg production. This is surprising because men are usually more endowed with resource inputs than women. However, women also generally control smaller farmlands than men, and this could also be in line with the above observation on farm size. In addition, women are key actors in the business of farming, both in terms of labour supply (Enete *et al*. 2002) and as decision makers (Enete and Amusa 2010). In many cases, farming is disproportionately their responsibility. They may therefore have acquired relatively more technical and managerial expertise on the job than men.

Table 3. Frequency distribution of technical efficiency of garden egg farmers

Efficiency level	Frequency	Percentage
0.50-0.59	0	0
0.60-0.69	5	5.56
0.70-0.79	4	4.44
0.80-0.89	19	21.11
0.90-0.99	62	68.89
Total Maximum value = 0.97 Minimum value = 0.61 Mean efficiency = 0.86	90	100

Source: field survey, 2009

Table 3 above shows the frequency distribution of technical efficiency of garden egg farmers. There is a variation in the level of efficiency among the farmers, ranging from 0.61-0.97% with a mean efficiency level of 0.86. However, 94.44% of the farmers had a technical efficiency of 70% and above. This implies that, on the average, farmers are able to obtain 86% of potential output from a given mix of production inputs. In the short run, there is scope for increasing garden egg output by 14% through the adoption of the techniques and technology employed by the best garden egg farmers. The implications of the results is that an average farmer could realize a 11.20% cost saving {i.e. 1-(86.4/97.3)*100} to achieve the technical efficiency level of its most efficient counterpart. A similar calculation on the most technically inefficient farmer reveal cost savings of 36.38% {i.e.1-(61.9/97.3)*100}.

6 Conclusions

The study estimates the levels of and determinants of farm level specific technical efficiency in garden egg production. The summary statistics indicated that farmers were young (with a mean age of 43 years) and educated, having had about 7.44 years of schooling. The result shows that garden egg farmers were not very efficient technically, although the mean efficiency is relatively high (86%). The production factors (and size, labour, fertilizer, manure and planting material) were all positive and significant. This implies that it was an increasing function. The major determinants of farm level efficiency were found to be farm size and gender. An increase in farm size was found to reduce efficiency. This finding is consistent with "Schultz's –poor-but-efficient hypothesis" that peasant farmers in traditional agriculture are efficient in their resource allocation given their operating circumstances (Schultz, 1964). In addition, women were found to be more efficient than men, perhaps also because they generally control smaller farm sizes than men. The size of technical efficiency obtained suggests that an average farmer in the sample is fairly efficient technically, though the efficiency could be improved by 14% through better use of available resources. These observations suggest that providing an enabling environment for urban smallholder farmers and perhaps resource rationalization between men and women could enhance their productivity and hence help in reducing urban poverty.

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