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Determinants of Technical Efficiency in Urban Food Crop Production in Ibadan Metropolis, Oyo State, Nigeria

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ABSTRACT. This study analysed the level and the determinants of technical efficiency among urban crop farmers in Ibadan metropolis. The random sampling technique was used in selecting 85 farmers from the following three areas where urban food crop production is prominent: Ajibode, Ijokodo, and Eleyele. The data were collected through structured questionnaires and analysed using both descriptive statistics and stochastic production frontier based on the Cobb-Douglas production function. The results reveal that farmland, family labour, and plantlings are statistical determinants of urban food crop production in the study area. Fertilizer and hired labour are, however, not statistically significant in influencing urban food crop production. The result of the determinants of technical efficiency model reveals that full-time occupation in urban farming and sole-cropping pattern were positively related to technical efficiency. An increase in the age, experience, and years of formal education of the urban farmers increases the level of technical efficiency. The policy implication is that there are still more opportunities to raise the present level of technical efficiency of urban crop production in the study area. Educating

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farmers so that they are more receptive to modern improved technologies coming from the agricultural research system can lead to higher output per unit of input. doi:10.1300/J108v07n04_05 [Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com> © 2006 by The Haworth Press, Inc. All rights reserved.]

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INTRODUCTION

Urban Agriculture has received international attention since the 1980s, but more so since the early 1990s. This may be as a result of the fact that a rapidly growing number of national and local governments have recognized the contribution urban agriculture can make to counteract the growing urban food insecurity (Van Veenhuizen, 2003). In many developing countries, urban agriculture is a necessity, as it supplements household food supplies, unlike in developed countries where it is practised as a leisure activity (Smit et al., 1996). Analyses of current trends regarding urban food systems reveal that, in order to achieve food security for the urban poor, a sole reliance on food produced in rural areas and imported food is insufficient. It is necessary for cities to develop plans to enhance urban and peri-urban food production (Dahlberg, 1998).

The scale of urban agricultural production in the world is far above common perceptions. It has been estimated that in 1993, as much as 15-20% of the world's food was produced in urban areas and that this percentage is on the increase. Also, an estimated 800 million people are engaged in urban agriculture worldwide, of which 200 million are considered to be producing for the market, employing 150 million people full-time (Smit et al., 1996). Urban agriculture has always been part of urban settlements in the past and, even today, many urban inhabitants turn to it as part of their livelihood strategy. Although the quantity of food produced by city farming does not equal to that grown outside the city, its impact is quite considerable (Smit et al., 1996). Agriculture in the city differs from that in the rural area with regard to location, economic motive, and type of product, among others.

In 1994, as much as 45% of the world's population lived in cities and, according to the United Nations Center for Human settlements (UNCHS-Habitat), it was expected that this percentage would increase to more

than 50% by the year 2000 and 65% by 2025. The United Nations (UN) also stated that the rate of urban growth is highest in Africa, at 4.4% a year. In 1990, as many as 288 cities in developing countries had a population of more than one million people and, by the year 2000, it was projected that there would be 391 such cities. Smit et al.'s (1996) projected figures for 2000 indicated that 63% of the estimated population of 430 million would be found in urban centers of West Africa by the year 2020. Most cities in developing countries are not able to generate sufficient (formal or informal) income opportunities for the quickly growing population. This situation is compounded by the fact that 50-70% or more of income is spent on food.

Having recognized the contribution of urban agriculture to some other countries, there is a great potential to boost the food production of Nigerians, whose urban population continues to rise through rural-urban migration. In order to enhance urban crop production, it is important to estimate the resource-use efficiency of urban food production in the Ibadan metropolis. Urban agriculture has beneficial impacts on food security for low-income urban residents. Rabinovitch et al. (1997) reported that, in the United States, 70% of fruits, vegetables, and ornamental plants are grown on urban land. Von Braun (1997) reported that, while poverty and food storage remain predominantly rural problems, the proportion of undernourished people living in cities is on the rise due to rural-urban migration. Therefore, urban farming will be beneficial because of the low purchasing power of the majority of migrants due to unemployment. Urban farming is a food production strategy that has been employed since Roman times to secure close-at-hand basic and supplementary food supplies. It is a practice that is growing due to its ability to assist, resolve, or cope with diverse development challenges. But despite the importance of urban agriculture, it has not been given its rightful place. This is because it has not been officially recognized; rather, it is merely tolerated as response to the socio-economic conditions faced by many poor individuals.

The study of the determinants of efficiency in resource use among urban farmers is still rare in Nigeria. One study that attempted this was that of Etim (2001) who investigated the South-South geo-political zone of Nigeria. His study identified the sources of technical efficiency and predicted the technical efficiency of urban crop farms using a stochastic production frontier approach in Ibadan metropolis, the largest city south of the Sahara.

THEORETICAL FRAMEWORK OF ANALYSIS

The level of technical efficiency of a particular firm is characterized by the relationship between observed production and some ideal or potential production (Greene, 1993). The measurement of firm-specific technical efficiency is based upon the deviation of observed output from the best production or efficient production frontier. If a firm's actual production point lies on the frontier, then the firm is said to be perfectly efficient in the use of the production input (Pascoe and Herrero, 2002).

Farrell's (1957) definition of technical efficiency led to the development of methods for estimating the relative technical efficiencies of firms. The common feature of these estimation techniques is that information is extracted from extreme observations from a body of data to determine the best practice production frontier (Lewis and Lovell, 1990). From this, the relative measure of technical efficiency for the individual firm can be derived. The approaches for estimating technical efficiency can be generally categorized under the distinctly opposing techniques of parametric and non-parametric methods (Seiford and Thrall, 1990).

Stochastic estimations incorporate a measure of random error. This involves the estimation of a stochastic production frontier, where the output of a firm is a function of a set of inputs, inefficiency, and random error. An often-quoted disadvantage of the technique, however, is that it imposes an explicit functional form and distribution assumption on the data. In contrast, the linear programming technique of data envelopment analysis (DEA) does not impose any assumptions about functional form; hence, it is less prone to misspecification. Furthermore, DEA is a non-parametric approach, so it does not take into account random error and, therefore, is not subsequently subject to the problems of assuming an underlying distribution with regard to the error term. However, since DEA cannot take into account such statistical noise, the efficiency estimates may be biased if the production process is largely characterized by stochastic elements (Pascoe and Herrero, 2002). The most commonly used packages for estimating stochastic production frontier and inefficiency are FRONTIER 4.1 (Coelli, 1996) and LIMDEP (Green, 1995).

FRONTIER 4.1 is a single-purpose package specifically designed for the estimation of stochastic production frontier (and nothing else), while LIMDEP is a more general package designed for a range of non-standard (i.e., non-OLS) econometric estimations. An advantage of FRONTIER 4.1 is that estimates of efficiency are produced as a direct output from the package and it is also able to accommodate a wider range of assumptions about the error distribution term than LIMDEP, although it is unable to

model exponential distributions or include gamma distributions. Only FRONTIER is able to estimate an efficiency model as a one-step process. (Pascoe and Herrero, 2002).

THE STOCHASTIC FRONTIER MODEL

The stochastic production frontier (SPF) representing Cobb-Douglas production technology characterized by variable return to scale is specified as

$$\ln Y_i = B_0 + \sum_{k=1}^K B_k \ln X_{ki} + V_i - U_i \quad i = 1, 2, \dots, n$$

$$K = 1$$

The error term is made up of two components, V_i and U_i . V_i is a two-sided conventional error that is independent of U_i and is assumed to be distributed as $N-C; (0, \sigma^2 v)$ (i.e., it is normally distributed with a mean of zero and constant variance). This component is supposed to capture statistical noise (i.e., measurement error) and random exogenous shocks that disrupt production. The second component U_i is also a random variable, but, unlike V_i , it is only a one-sided variable taking non-negative values. This term captures technical inefficiency of production. There is no consensus among econometricians as to what specific distribution U_i should have.

In previous empirical studies, a variety of distributions, ranging from the single-parameter, half-normal, exponential, and truncated normal distributions to the two-parameter gamma distribution, have been used by Bravoureta and Reiger (1990), Battese (1992), and Sharma, Levung, and Zaleski (1999). The values of these models are usually estimated by maximum likelihood.

In this study, the Cobb-Douglas production function was used, because it has been the most commonly used function in the specification and estimation of production frontier in empirical studies (e.g., Seyoum et al., 1998; Ajibefu and Daramola, 1999). It is attractive due to its simplicity and because the logarithmic nature of the production function makes econometric estimation of the parameters a very simple matter. Yin (2000) points out that this function may be criticized for its restrictive assumptions, such as unitary elasticity of substitution, constant returns to scale, and input elasticity. Other functional forms, such as Translog production functions, that are not based on restrictive assumptions have

their own limitations, such as being susceptible to multicollinearity and degree of freedom problems.

A study done by Kopp and Smith (1980) suggests that functional specification has only a small impact on measured efficiency. Coelli and Battese (1996) point out that, if an industry is not characterized by perfectly competitive producers, the use of a Cobb-Douglas functional form is justified.

METHODOLOGY

The sample size of this study is 85 urban crop farmers. The random sampling technique was used in selecting the farmers practising urban farming within the Ibadan metropolis. Ninety urban crop farmers were given the structured questionnaires, and they were randomly selected from the areas where urban crop farming is predominant (Ajibode, Eleyele, and Ijokodo). Thirty structured questionnaires were randomly given to urban crop farmers in each of the areas; 85 questionnaires were returned: 28 from Ajibode, 30 from Eleyele, and 27 from Ijokodo.

The information was coded and analysed through the use of descriptive statistics: Frequency count, percentage, and histogram, and stochastic production frontier. A multiple regression model based on stochastic production frontier was used to measure resource-use efficiency in urban crop farming in the study area. The stochastic production frontier for urban crop farmers in Ibadan metropolis is defined as:

$$\begin{aligned} \ln Q = & b_0 + b_1 \ln(\text{land}) + b_2 \ln(\text{Hired labour}) \\ & + b_3 \ln(\text{Family labour}) + b_4 \ln(\text{fertilizer}) \\ & + b_5 \ln(\text{Plantlings}) + V_i - U_i \end{aligned} \quad (1)$$

Where the technical inefficiency is hypothesised to be influenced by:

$$\begin{aligned} m_i = & d_0 + d_1(\text{Age}) + d_2(\text{Education}) + d_3(\text{Experience}) \\ & + d_4(\text{Gender}) + d_5(\text{Purpose}) + d_6(\text{Cropping Pattern}) \end{aligned} \quad (2)$$

And where \ln denotes the natural logarithm (i.e., logarithm to the base e).

Q = The total quantity of crop mix in each urban farm standardized as grain equivalent.

Land is the hectare of cultivated land

Labour is the family and hired labour, expressed as adult male equivalent in man-days.

Fertilizer is expressed in kilogramme

Plantlings is the value of seeds and other planting materials.

Age is the age of the urban crop farmers in years

Education is the years of formal education of the farmer.

Experience is the experience of the urban crop farmer in farming (in years).

Gender is the sex of the farmers ($D = 1$ for male and zero otherwise).

Purpose represents the primary purpose of farming ($D = 1$ for subsistence and zero otherwise).

Cropping pattern: $D = 1$ if mixed-cropping and 0 if sole-cropping.

The stochastic production frontier in Equation (1) is a linearised version of the Cobb-Douglas production function. The stochastic production frontier in Equation (1) and the inefficiency model in Equation (2) were simultaneously estimated, as proposed by Coelli (1996). The maximum-likelihood estimate of the parameters of the model was obtained using the FRONTIER 4.1 program. The maximum likelihood estimation procedure was used because it is asymptotically normally distributed. (Coelli, 1996)

The error terms in Equation (1) are V_i and U_i . The first component of error term, V_i , is a two-sided conventional random error term that is independent of U_i and assumed to be normally distributed with constant variance and mean of zero (i.e., $N(0, \sigma_v^2)$). This component is supposed to capture statistical noise (i.e., measurement error) and random exogenous shocks such as bad weather and diseases that disrupt production. The second component, U_i , is also a random variable but, unlike V_i , it is only a one-sided variable taking non-negative values. This term captures technical inefficiency of an urban crop farm in producing output.

RESULTS AND DISCUSSION

The estimated parameter and the related statistical test results obtained from the analysis are presented in Table 1. The log-likelihood function is estimated to be 55.86, which maximizes the joint densities in the estimated model. Sigma-squared (σ^2) has the value of 0.0186, meaning that the variation that occurs in the technical efficiency of the farms is caused by 1.86% of the error term (measurement error). Gamma (γ) is statistically different from zero, which implies that technical

TABLE 1. The Final Maximum-Likelihood Estimates (MLE) and Efficiency Function

	Coefficient	t-Ratio
Constant term (β_0)	2.5938	8.6916***
Land (ha) (β_1)	0.5959	7.9476***
Fertilizer (KG) (β_2)	-0.0054	-0.3904
Hired labour (man-days) (β_3)	0.0148	1.3776
Family labour (man-days)	0.0899	1.6763 *
Plantlings (#) (β_4)	0.1979	2.4027**
Efficiency Model		
Intercept (δ_0)	0.6715	7.6526***
Age (year) (δ_1)	0.0095	3.5853***
Education (δ_2)	0.1926	2.9191***
Experience (Year) (δ_3)	0.0037	4.9259***
Gender (δ_4)	0.0234	0.3339
Primary purpose (δ_5)	0.0497	0.8152
Household size (δ_6)	0.0054	0.7804
Cropping System (δ_7)	-0.1362	-1.8821*
Occupation (δ_8)	0.1403	1.9680 **
Diagnostic Statistics		
Sigma-squared (σ^2)	0.0186	5.2659 ***
Gamma (γ)	0.6282	2.4515**
Log likelihood Function	55.8605	
LR test	29.3172	
Number of observations	85	
Mean Efficiency = 0.68		

***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.

efficiency plays a significant role in the variation of observed urban farm output. The estimated value of Gamma in the model, 0.6282, implies that 12.8% of the total variation in urban farm output is due to technical inefficiency. The negative sign of the parameters in the inefficiency function means that the associated variables have a positive effect on the technical efficiency, and a positive sign indicates the reverse. Coefficient values indicate elasticities.

The estimated coefficient (0.5959) for land is positive and statistically significant at 1%, meaning that land is an important factor in explaining

variations in output. If the land size were increased by 10%, output level would rise by 5.959%, all other things being equal (*ceteris paribus*). This implies that the magnitude of the coefficient shows inelastic nature of output with respect to land. The elasticity of output with respect to fertilizer is negative and not statistically significant, showing that fertilizer is not an important factor in crop production in Ibadan metropolis. The production elasticity with respect to hired labour is positive but not statistically significant, showing that hired labour is not an important factor in crop output. The production elasticity of family labour is positive and statistically significant at 10%, showing that family labour appears to be an important factor in explaining variations in crop output. The magnitude of the coefficient shows inelastic nature of output with respect to family labour. If family labour is increased by 10%, output level would improve unproportionately by a margin of 0.899% in a *ceteris paribus* case. Therefore, there is still some potential to increase output by increasing the amount of family labour. The production elasticity of output with respect to the cost of plantlings is 0.1979, showing an inelastic situation. If the amount spent on plantlings were increased by 10%, output level would improve by a margin of 1.979% in a *ceteris paribus* case. The coefficient is statistically significant at 5%. This shows that there is still some potential to increase crop production per plot by increasing the amount spent on plantlings, especially when the land area can be increased.

DETERMINANTS OF EFFICIENCY AMONG THE URBAN FARMERS

The resulting determinants of efficiency (as outlined in Equation 2) are shown in Table 1. The efficiency factors are those relating to the farmers' specific socio-economic characteristics. These include age, farming experience, gender, cropping system, occupation, the years of formal education, the primary purpose of urban farming, and household size. Of these, age, primary occupation, experience, cropping pattern, and educational level are significant determinants of efficiency while all others are not.

The coefficient (0.0095) of age is positive and statistically significant at 1%, showing that, as age increases, efficiency in resource use in urban farms decreases. A 10% increase in age will lead to 0.09% increase in efficiency. The coefficient (0.19926) of the educational level of a farmer is positive but statistically significant at 1%, showing that, as the

educational level of the urban farmer increases, efficiency in resource use increases—that is, the more education, the less technical inefficiency. When the years of formal education are increased by 10%, efficiency is increased by 1.9926%. The coefficient (0.1926) of farming experience is positive and statistically significant. This shows that the efficiency in resource use by urban farmers increases with the years of urban farming experience. A 10% increase in farming experience increased efficiency by 1.96%. The coefficient (0.0234) of gender is not statistically significant. The coefficient (-0.1362) of cropping system is statistically significant at 10%. This shows that practice of the mixed cropping system negatively affects the technical efficiency of the farmers (i.e., farmers practising sole-cropping are more efficient than those practising mixed cropping). The majority of the urban farmers practised mixed cropping, thus reducing technical efficiency. The coefficient (0.1403) of the nature of occupation of farmers is statistically significant at 10%, showing that a primary occupation in urban farming is positively associated with higher levels of technical efficiency—that is, farmers that practise urban farming as a primary occupation are more efficient than farmers that practise urban farming as a secondary occupation.

TECHNICAL EFFICIENCY AMONG URBAN FARMERS

Table 2 and Figure 1 show the frequency distribution of technical efficiency estimates of the farmers. As shown in the table, a majority of the farmers have an efficiency value ranging from 0.6 to < 0.7 ; only about 4% of the farmers have efficiency values ranging from 0.2 to < 0.3 . The average technical efficiency value among the urban crop farmers in the study area was 0.68. None of the farmers had an efficiency value of 1.0, that is, 100% efficient in the stochastic production frontier model.

CONCLUSION AND POLICY RECOMMENDATIONS

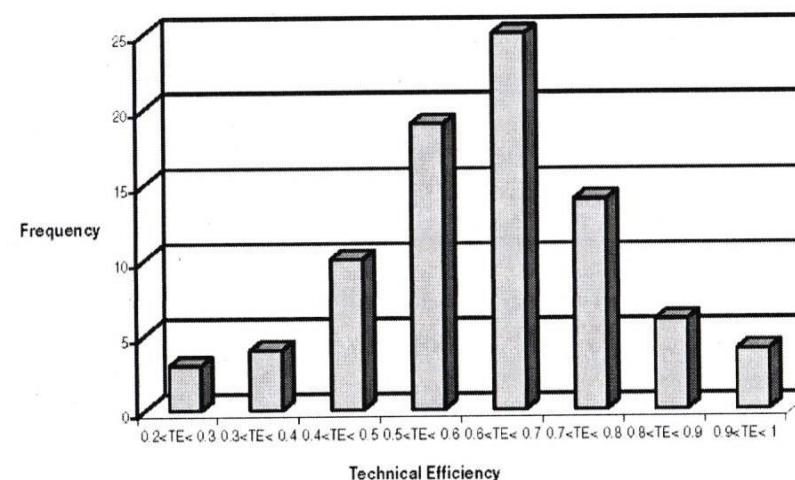
The Maximum-Likelihood Estimate (MLE) result reveals that farm size, family labour, and plantlings are the major factors associated with changes in the output of urban crops. Their coefficients show that any increase in these inputs leads to an increase in the output of crops produced by urban farmers. The coefficients of age, years of education, and experience of farmers are positive, meaning that an increase in these factors leads to an increase in the level of efficiency among urban farm-

TABLE 2. Frequency Distribution of Technical Efficiency of Urban Farmers

Technical efficiency	Frequency	Percentage
$0.2 < TE \leq 0.3$	3	3.53
$0.3 < TE \leq 0.4$	4	4.71
$0.4 < TE \leq 0.5$	10	11.76
$0.5 < TE \leq 0.6$	19	22.35
$0.6 < TE \leq 0.7$	25	29.41
$0.7 < TE \leq 0.8$	14	16.47
$0.8 < TE \leq 0.9$	6	7.06
$0.9 < TE \leq 1$	4	4.71
Total	85	100.00

Mean efficiency = 0.68

FIGURE 1. Frequency Distribution of Technical Efficiency Estimates of the Farmers



ers. In addition, the practice of a mixed cropping system and urban farming as a secondary occupation are associated with decreased levels of technical efficiency.

In view of these findings, it is recommended that urban farmers be educated in order to be able to derive maximum benefits from improved technologies. With increased education, farmers are better able to adopt

new yield-enhancing innovations coming from the agricultural research system. Farmers should also be encouraged to minimize the number of crops planted on the same plot of land, in order to achieve higher levels of efficiency in production.

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