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Application of Stochastic Frontier Analysis in the Estimation of Allocative Efficiency of Part-time Food Crop Farmers in Kogi State, Nigeria

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Abstract
In this paper, stochastic frontier cost model is used to analyze the allocative efficiency of part-time food crop farmers in Idah Local Government Area of Kogi State, North Central Nigeria and also to establish the socio-economic factors that determine allocative efficiency. It is evident from the study that part-time food crop farmers are not fully efficient in their allocation of production resources. This was confirmed by the presence of allocative inefficiency effects in part-time food crop farming with average allocative efficiency of 97.95 %. The study also revealed that rising age and household size contribute to allocative inefficiency in part-time food crop farming, while level of education and farming experience were found to increase allocative efficiency among the part-time food crop farmers. It is recommended that policies aimed at encouraging relatively younger and educated persons and providing them easy access to improved seeds and fertilizers should be formulated .This will go a long way in enhancing allocative efficiency in part-time food crop farming.
Keywords*:* Part-time farming, stochastic frontier cost model, allocative efficiency

1. Introduction

The agricultural sector contributes about 41% of the Gross Domestic Product (GDP), employs about 65 percent of the total population and about 80 percent of the rural population (CBN, 2002). Agriculture also provides about 90 percent of the nation's total food requirements and merits priority attention from policy makers not only because of its economic significance but also because of its importance in the war against poverty (Ruma, 2008). Although farming has always been complemented by non-agricultural employment in crafts activities during slack period in the agricultural year, other dimensions have evolved. There is a situation in which full-time farmers divide their working time even during peak farming seasons, between farming and non-farming activities (off-farm activities); another is one in which a wage earning individual or household take up farming on part-time basis especially around urban and suburban towns (Okafor,1982).. The increasing demand for food and jobs in urban and suburban areas made it necessary for employed wage earning urban and sub-urban dwellers to practice part-time farming as a means of filling the food demand and supply gap and providing income to supplement their wages (Umoh,2006). The part-time farmers like other farmers will typically produce to satisfy household food needs or make profit from selling or both. If the production were for household consumption, then the farmer will aim at obtaining the optimum output from his or her effort. If on the other hand, the part-time farmer produces for market to earn income to supplement wages, then the cost of production and returns accruable to the farmer's production effort becomes an important measure of performance. Either of the two objectives of production requires efficient use of farm resources. Efficiency is at the heart of agricultural production. This is because the scope of agricultural production can be expanded and sustained by farmers through efficient use of resources (Ali, 1996; Udoh, 2000).

Empirical studies on efficiency of part-time farming in Nigeria are scant and far between . Few of such studies (e.g Udoh, 2005 and Umoh, 2006) paid particular attention to urban farming with little or no attention paid to part-time farming. The question therefore is: Are part-time farmers efficient in the allocation of production resources? This study is an attempt to answer this question with specific emphasis on allocative efficiency in part-time food crop farming.

The purpose of this study is to analyze empirically, the allocative efficiency of resource use in part-time food crop farming. The specific objectives are to : (i) examine the socio-economic characteristics of part-time farmers, their cropping pattern and (ii)determine the allocative efficiency of resource use in part-time farming.

1.2 Conceptual Framework

The main feature of the stochastic frontier functions is that the disturbance term is composed of two parts: a symmetric and a one- sided component. The symmetric component v_i captures the random effects due to the measurement error, statistical noise and other non-symmetric influences outside the control of the firm. It is assumed to have a normal distribution. The one-sided (non-negative) component, u_i with $u_i \geq 0$, capture the technical inefficiency relative to the stochastic frontier. This randomness is under the control of the farmer; its distribution is assumed to be half normal or exponential. The v_i are assumed to be independently and identically distributed as; N $(0,\sigma_v^2)$ random variables, independent of u_is. The u_is are also assumed to be independently and identically distributed as exponential (Meeusen and van den Broeck, 1977), half normal (Aigner et al, 1977), truncated and gamma (Greene, 1990).

The stochastic frontier cost model of Cobb-Douglas functional form is employed to estimate the firm-level allocative efficiencies. The Cobb-Douglas functional form is widely used in farm efficiency studies in developed and developing countries and it meets the requirement of being self-dual, allowing an examination of economic efficiency (Ogundari and Ojo, 2007).

The stochastic frontier cost function is typically specified as follows:

$$C_i=f(P_i;\alpha)\exp(v_i+u_i) i=1,2,\ldots,n \quad (1)$$

Where C_i represents the total input cost of the i-th farm; f is a suitable functional form such as the Cobb-Douglas function; P_i represents input prices employed by the i-th farmer in production; α_I represents the parameter to be estimated, v_is and u_is are random errors and assumed to be independent and identically distributed truncations of $N(\mu,\sigma^2)$ distribution. The u_i provides information on the level of allocative efficiency of the i-th farm. The allocative efficiency of individual farmers is defined in terms of the ratio of the predicted minimum cost (C_i^*) to observed cost (C_i).

That is:

$$AE_i=C_i^*/C_i=\exp(u_i) \quad (2)$$

Allocative efficiency ranges between zero and one.

The use of stochastic frontier analysis in studies in agriculture in Nigeria is a recent development. Such studies include Udoh (2000), Ojo (2004), Umoh (2006), Ogundari and Ojo (2007),Oji and Chukwuma (2007) and Amodu(2010) .

2. Research Methodology

2.1 Study Area

The study is based on farm level data collected from part-time farmers in Idah Local Government Area of Kogi State of Nigeria in the 2009-2010 farming season. Idah is located within the following coordinates: North 7^0N, and 7^0 East. Idah is the smallest of the 21 LGAs in Kogi state in terms of land mass and Igala is the language predominantly spoken by the people. Kogi state is located in North Central Nigeria and is a predominantly agrarian state. Located in the eastern senatorial district of the State, Idah LGA is bounded on the east and north by Igalla-mella Odolu LGA, on the south by Ibaji LGA and on the east by Etsako L.G.A of Edo state from which it is bounded by the River Niger. A wide range of crops and wood plants grow here under rain fed cultivation. Agriculture forms the principal means of livelihood of 80 percent of the population (Idachaba, 2005). Farming is the traditional occupation with emphasis on food grains and tubers.

2.2 Data Collection Procedure

The data were collected from 110 part-time food crop (maize, cassava and yam) farmers selected using the multi-stage random sampling technique. The first procedure was the purposive sampling of wage earning employees of Federal, State, Local Government and Non-governmental organizations who engage in part-time food crop farming. The second stage involved the disproportionate selection of respondents using the simple random sampling method to constitute the sample from the list of employees made available for this study. Data were collected from part-time farmers in the 2009-2010 cropping season using structured questionnaires. Information collected on the socio-economic characteristics of the part-time farmers includes educational status, age, household size, and farming experience. The output data include the total value of the commonly grown crops obtained by adding cash receipts from sold produce plus those consumed in the household. The cost function data include; cost of land preparation, cost of labour, and cost of planting materials, cost of fertilizer used and other operating expenses.

2.3 Methods of Data Analysis

Data collected were subjected to the following tools of analysis; Descriptive Statistics was used to characterize the part –time farmer while stochastic frontier cost model was used to estimate the allocative efficiency of the farmers.

2.3.1 The Stochastic Frontier Cost Function

The model used in this study is based on the one proposed by Battese and Coelli (1995) in which the stochastic frontier specification incorporates models for the allocative inefficiency effects and simultaneously estimate all the parameters involved in the cost function model.

The Cobb-Douglas cost frontier function for the farmers was specified and defined as follows:

$$LnC=\ln\alpha_0+\sum\alpha_{ij}\ln P_{ij}+V_i+U_i \quad (3)$$

Where;

C_i =Total cost of production of i-th farm (in Naira); P_1=Cost of land preparation (in Naira);P_2=Cost of labour used in production (in Naira); P_3=Cost of planting materials (in Naira);P_4=Cost of fertilizers (in Naira); P_5=other operating expenses (in Naira); α_0 =Intercept; α_{ij} =Vector of cost function parameters to be estimated; v_i = Random variability in the cost of production that cannot be influenced by the farmer. μ_i = the deviation from the cost frontier attributable to allocative inefficiency.

The allocative inefficiency affect μ_i is defined by:

$$\mu_i=\delta_0+\delta_1 Z_{1i}+\delta_2 Z_{2i}+\delta_3 Z_{3i}+\delta_4 Z_{4i} \quad (4)$$

μ_i = allocative inefficiency effect of the i^{-th} farm

Where; Z_1, Z_2, Z_3, and Z_4 respectively are; age of the farmer, educational level, household size, and farming experience. These are included in the model to indicate their possible influence on the allocative efficiencies of the part-time food crop farmers.

The β and δ are unknown parameters to be estimated along with the variance parameters δ^2 and γ. The variance of the random error δv^2 and that of the allocative inefficiency effect $\delta^2 u$ and the overall variance of the model are related as follows:-

$$\delta^2=\delta_v^2+\delta_u^2 \quad (5)$$

$$\gamma=\delta_u^2/\delta^2 \quad (6)$$

Equation (6) measures the total variation of cost from the frontier which can be attributed to allocative or cost inefficiency (Battese and Corra, 1977).The δ^2 and γ, coefficients are the diagnostic statistics that indicate the relevance of the use of the stochastic frontier function and the correctness of the assumptions made on the distribution form of the error term. The δ^2 indicates the goodness of fit and the correctness of the distributional form assumed for the composite error term. The γ, indicates that the systematic influences that are unexplained by the production and cost function are the dominant sources of random errors. The statistical significance of these shows the presence of one- sided error component, v_i in the model specified. Because of the presence of this one-sided error component, the traditional response function estimated by the ordinary least square cannot adequately represent the data, hence the use of the stochastic frontier function estimated by the Maximum Likelihood Estimation procedure.

The estimates for all the parameters of the stochastic frontier function and the inefficiency model were simultaneously obtained by the Maximum Likelihood Estimation method using the computer program FRONTIER version 4.1c (Coelli, 1996).

3. Results

3.1 Socio-economic Characteristics and Cropping Pattern of Part–Time Food Crop Farmers

Table 1 shows the average age of the part time farmers was 40 years with a standard deviation of 10 years. This shows that the farmers were relatively young. The average educational level attained was 3.32 with a standard deviation of 0.18 showing that the part–time farmers where educated persons. The mean household size of the part time farmers was 5.23 with standard deviation of 2.45 indicating a relatively small household size. The average farming experience of the part–time farmers was 10.75years with a standard deviation of 5.24 years. Part-time food crop farmers in the study area were found to cultivate between 0.5 ha and a maximum of 5 ha. The crops grown varied widely but the most economically significant from the perspective of the farmers are the crops shown in Table 2. The main crops grown in the area by part-time farmers are maize, cassava, and yams. The study revealed that about 73% of part-time farmers cultivated maize in season and about 27% of them grow yam. All the part-time farmers own cassava farms.

Table1. Summary Statistics of Socio – Economic Characteristics

Variables	Maximum	Mean
Part-time farm income(Naira)	**450,000**	**159,154.31**
Age (Yrs)	**62**	**40.30**
Education	**5**	**3.32**
Household Size	**12**	**5.23**
Farming Experience(Yrs)	**25**	**10.75**
Salary Income(Naira)	**1,500,000**	**708,300**
Farm Size (Ha)	**5**	**1.83**

Source: Field survey, 2010

Table 2. Dominant Crops Grown by Part-time Food Crop Farmers and Average Area Cultivated

Crop Grown	No of Farmers	Percentage	Average Farm Size(Ha)
Maize	80	73	1.30
Yam	30	27	0.50
Cassava	110	100	1.80

Source: Field survey, 2010

3.2 Stochastic Frontier Cost and Allocative Inefficiency Model Analysis

The estimates of the parameters of the stochastic frontier cost model of part-time farmers in the study area are presented in Table 3. The variance parameter estimate for sigma squared (σ^2) and gamma (γ) are 0.25 and 0.58 respectively. They are significantly different from zero at 1percent level of significance. This means that cost inefficiency effects do make significant contributions to the cost of production of part-time farmers in the study area. The estimated gamma γ parameter of 0.586 indicates that about 59 percent of the variations in the total cost of production of part-time farmers were due to differences in their allocative efficiencies. Thus, the hypothesis that the parameter estimate of γ=0 is rejected. The result shows that allocative inefficiency effects were present. This was confirmed by the test of hypothesis using the Log Ratio Test. The Log Ratio (LR) test is 18.47 while the critical value of the chi-square at 5 percent level of significance with 6 degrees of freedom χ^2(5%,6) was 12.60. The estimated coefficients of the parameters of the cost function are positive. The implication of this is that the cost variables have direct relationship with total cost of production. All the cost variables are significant at 5 percent level of significance except the cost of fertilizer.

Table 3. Maximum Likelihood Estimates of the Stochastic Frontier Cost Function

Variable	Parameters	Coefficients
Cost model:		
Constant	α_0	4.01* (13.83)
Land preparation	α_1	0.20* (3.48)
Labour	α_2	0.21* (5.05)
Planting materials	α_3	0.19* (3.90)
Fertilizer	α_4	0.030^{NS} (0.96)
Other variable expenses	α_5	0.14* (2.57)
Inefficiency model:		
Constant	δ_0	0.18 $(1.47)^{NS}$
Age	δ_1	0.068* (2.038)
Education	δ_2	0.522 (-2.056)
Household	δ_3	0.209* (6.34)
Farming Experience	δ_4	0.672* (-3.042)
Variances:		
Sigma square	σ^2	0.25* (8.579)
Gamma	γ	0.58* (6.454)
Log likelihood function	*Llf*	47.7
		LR test 18.47

*Figures in parenthesis are t-ratio. Estimate is significant at *5% level and below*

[+] *A negative sign on a parameter indicates a positive impact on efficiency.*

3.3 Farm Level Allocative Efficiency

The estimates of farm level allocative efficiency levels were simultaneously obtained using the Maximum Likelihood Estimation method run on the computer program FRONTIER version 4.1c (Coelli, 1996) are as in Table 4.

Table 4. Distribution of Farm Specific Allocative Efficiency Indices

Efficiency Level %	Frequency	%
25-50	-	-
51-75	-	-
76-95	-	-
96-100	110	100
Total	110	100
Minimum (%)		96.10
Maximum (%)		99.80
Mean (%)		97.95

Source: Analyzed from field survey data, 2010

4. Discussion

4.1 Socio-economic Characteristics and Cropping Pattern of Part–Time Food Crop Farmers

On age classification, Sing and Williamson (1981) in their study of part-time farming in Tennessee State USA indicated that part-time farming was negatively related to age. The present study shows a relatively young population. This may be attributed to the fact that these groups of farmers are not engaged full–time and are not essentially rural based. The implication of this is that if, production inputs are readily available, part–time farming can substantially augment agricultural output where the population of rural farmers is aging. The educational level of the farmers is known to affect their farming activities.

It is a documented fact in agricultural extension that farmers with higher level of educational qualification more readily adopt agricultural technological innovations than those without or with lower qualifications (Osuji, 1983). The study reveals that most of the part-time farmers have secondary and tertiary education. The study shows that even persons with superior academic qualifications engage in part-time farming, contrary to perception of farming as a vocation for illiterate people. The relevance of household size as a factor in the analysis of part-time farming lies in the assumption that increasing household size will put pressure on household food demand and income. Thus it is necessary to look at household size in the socio-economic characterization of part-time farmers in the study area. This result shows that most of the part-time farmers had experience, implying that they are likely to make better decisions to enhance productivity and income.

The basic assumption would be that only low income workers will engage in part-time farm ing and those that engage in this activity do so mainly to augment their income. Empirical evidence suggests that this is not necessary so. According to Tacoli (1997), some studies have shown that high and middle income households constitute a significant and growing proportion of urban farmers, who often engage in this activity for commercial purposes. The result of this study supports this position. The study shows that the part–time farming population includes the low as well as the high salary income earners. This implies that part-time farming may be driven by other factors more than subsistence needs.

Farm size, particularly the area of land cultivated is an important factor as it determines the level of output the farmer can get, *ceteris paribus*. Olayide et al (1981) and Todaro (1992) defined small scale farmers as those cultivating not more than three to five hectares of farm land. Obasi *et al,* (1994) in their study of some selected factors that influence the adoption of improved farm practices among soya beans farmers in Benue State, noted that majority of the part-time soya farmers were small scale in operation cultivating between 1-3 hectares of farm land. Part-time farmers in the study area are mostly small scale in operation. The main crops grown in the area by part-time farmers are maize, cassava, and yams. The generally adduced reason for growing these crops is the commercial value they are able to derive from selling, particularly maize and yams. Farmers in the study area, practice split plot mono-cropping. They usually cultivate these crops on various plots of farm land in different locations.

4.2 Stochastic Frontier Cost Model Analysis

The result of the stochastic frontier cost function model is discussed as follows; The coefficient of the cost of land preparation was found to be positive and significant at 5 percent level. If the land area put into production is increased by 10 percent, total cost of production will increase by less than proportionate margin of 2 percent. This means that as the size of land area put into production increases, the cost of land preparation increases. The implication of this is that part-time farmers' total cost of production is increased as more land is put under cultivation. The coefficient of the cost of labour was significant and had a positive sign. This shows the importance of labour as a major cost item in part-time farming in the study area. This is in line with several studies that have confirmed the importance of labour in farming. The magnitude of the coefficient of the cost of labour shows that total value of cost of production will increase by 2 percent if the cost of labour is increased by 10 percent. The implication of this is that the cost of labour is a major contributor to the total cost of production in part-time farming in the study area. The coefficient of the cost of planting materials was positive and significant at 5 percent level of significance. This implies that planting materials are important in crop production in part-time farms. However the contribution of this cost item to total cost of production is very marginal. The cost elasticity with respect to fertilizer is 0.03. By increasing the cost of fertilizer by 10 percent, the total cost of production will only increase by 0.3 percent. The estimated coefficient of the cost of fertilizer is positive but not significantly different from zero at 5 percent level. This may be traceable to the low level of fertilizer use reported by the part-time farmers in the study area. The estimated coefficient for other variable expenses is positive and significant at 5 percent level of significance. The cost elasticity of other variable expenses is 0.14, implying that a 10percent increase in other variable expenses will lead to 1.40 percent increase in the total cost of production.

4.3 Allocative Inefficiency Model

The variables of the allocative inefficiency model are shown in Table 3 and discussed as follows;The coefficient of age of part-time farmers is positively related to allocative inefficiency and significantly different from zero at 5percent level of significance. The implication of this is that age contributes to allocative inefficiency in part-time farming in the study area. The coefficient of level of education is negatively related to allocative inefficiency and significant at 5 percent level of significance. The implication of this is that the level of education of the part-time farmers increases their ability to manage production costs efficiently. The coefficient of household size in the allocative inefficiency model is positive and significantly different from zero. The implication of the coefficient of household size on allocative inefficiency is that it decreases the allocative efficiency of part-time farmers in the study area. Farming experience of the part-time farmers in the allocative inefficiency model is negative and significantly different from zero at 5 percent level of significance. The coefficient of farming experience indicates that it decreases allocative inefficiency in part-time farming. The implication of this is that the part-time farmers' experience affects their cost efficiency in the allocation of production resources on their farms. The implication of this finding is that the personal characteristics of the part-time farmers had effect on their allocative efficiency. The findings of this study are in agreement with Ogundari and Ojo(2007) who in their study found years of schooling and farming experience to be negatively related to allocative inefficiency and significant at 5 percent level.

4.4 Farm Level Allocative Efficiency

The frequency distribution of predictive individual farm level allocative efficiencies shows that about 100 percent of the part-time farmers in the study area have allocative efficiency scores of over 90 percent with an average score of 97.95percent.This implies that the capacity of part-time farmers to produce at allocatively efficient level is very high.

5. Conclusion and Recommendation

The part-time farmers were allocatively efficient in their use of resources even though inefficiency effects were present. This is obvious from the test of hypothesis and the significance of the gamma (γ) parameter in the inefficiency model. Allocative inefficiency in the study area is increased by age, household size and farming experience while education enhances allocative efficiency.

The findings of this study have implications for increased food production, household food security and income supplementation. The fact that part-time farming is engaged in by both low and high income earners makes it imperative for government to recognize the practice for accommodation in its agricultural policy formulation. The 98 percent level of mean allocative efficiency shows that the farmers are very efficient in the allocation of their production resources. Optimum allocative efficiency of 100 % can be achieved through the initiation and implementation of policies that make farming attractive to educated individuals. This derives from the fact that education enhances both technical and allocative efficiency in part-time farming.

Part-time farmers should be encouraged to form themselves into cooperative groups to enable them easier access to production inputs such as fertilizer as well as credit at lower costs. Governments at all levels should initiate programs on farm machinery hire services so that farmers can have easy access to tractors and implements. This is aimed at checking the high cost of labour input in farming so as to further improve allocative efficiency. It is also recommended that educated young men currently in employment be encouraged to participate in part-time farming.

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