Economic Efficiency of Orange-Fleshed Sweetpotato Vine Production in North Central, Nigeria: A Translog Stochastic Frontier Cost Function Approach

Teryima Jude Nyor* Anayochukwu Jude Mbanasor Okore Philips Nto
Department of Agribusiness and Management Michael Okpara University of Agriculture, Umudike – Nigeria
P.M.B 7267, Umuahia, Abia State, Nigeria

Abstract
The study employed a translog stochastic frontier cost function to measure the level of economic efficiency and its determinants in orange-fleshed sweetpotato (OFSP) vine production system in North – Central Nigeria. A multistage sampling technique was used to select 139 OFSP vine entrepreneurs in Benue, Nasarawa and Kwara States from whom data were collected on input-output, their prices, farmer and farm characteristics with the aid of a structured questionnaire designed for a single visit. The results of the analysis showed that the mean economic efficiency of OFSP vine entrepreneur was 56 percent. The study found that age and household size to be negatively assign and significant at 10 % and 1 % respectively while education, gender, farm experience, extension visit and access to credit were significant and have positive influence on economic efficiency at 1.0% level of probability. No significant relationship was found between production system and economic efficiency. The study recommends policy decision that encourage new entrepreneurs to take up OFSP vine production and existence ones to remain in business through increased access to education, extension services and credit.
Keywords: Economic efficiency, orange-fleshed, sweetpotato, vine, North central

1. Introduction

Orange-Fleshed Sweetpotato (OFSP) is an improved breed of sweetpotato (*Ipomea batatas* [L.] *Lam.*) cultivated in tropical and semi-tropical regions of the world for food and source of income especially among the rural dwellers (Adebisi, *et al.,* 2015; Padmaja, 2009; Mitra, 2012). It can be grown in wide range of agro-ecologies and soil types. OFSP is easy to cultivate, it is a crop with immense ability to grow in marginal fields (Afuape, 2014). It can be vegetatively propagated, and has fairly drought resistant ability once established. It has short maturity period compare to other root and tuber crops. These characteristics make OFSP an excellent food security crop in Sub-Saharan Africa (Low, *et al*., 2007).

In Nigeria, OFSP like other breeds of sweetpotato is grown in all parts of the country, however commercial cultivation appears to be concentrated in Northern, semi-arid agro ecological zone of the country covering Benue, Nasarawa, Plateau, Kogi, Kwara, and Niger states (Amienyo and Ataga, 2007; Sweetpotato Support Platform for West Africa, SSP-WA, 2012 in Anderson and Gugerty, 2012). Sweetpotato has a number of agricultural and industrial uses as well. Sweetpotato vines, leaves and roots are used for animal feed for sheep, goats, and rabbits (Tewe, *et al*., 2003). Sweetpotato can also be exploited for ethanol and biofuel production. Sweetpotato can be processed to yield about 137 liters of ethanol per metric ton of sweetpotato tubers (Akoroda, 2009). Like other breeds of sweetpotato, OFSP can be grown under different production systems. While some farmers prefer sole cropping system, others intercrop sweetpotato with pigeon pea to ensure better environmental resource utilization, better yield stability, reduction in pests and diseases and diversification of rural income.

However, timely access to adequate quantities of quality vines (seed) as planting materials has been cited as one of the major constraints to the realisation of the full potentials of OFSP production in Sub-Saharan African (Coomes *et al.,* 2015; McGuire and Sterling, 2016; McEwan *et al*., 2015). This ugly situation is compounded by the failure of the formal seed delivery system and the perishable, bulky nature of the OFSP vines. The limited role plays by the institutional seed sector in providing timely and quality vines to farmers has given birth to a flourishing informal decentralized and local vine multiplication system (Kimenye and McEwan, 2014; McEwan *et al.,* 2017). Therefore, it is imperative to strengthen and leverage on the informal vine multiplication efforts for timely dissemination of healthy and quality vines to farmers to improve OFSP production.

Farm efficiency has fuelled a large body of literature globally and is of importance both from microeconomic and macroeconomic points of view. Improving the efficiency with which farmers use the available resources is very crucial to increasing production, productivity, household income, food security, poverty reduction and overall economic growth. An efficient OFSP enterprise will naturally attract more investment. Previous studies on OFSP, for example, Low, *et al.,* (2015); Laurie *et al*.,(2015); Agili, *et al.,* (2015); Abidin *et al*.,(2015); Chima, *et al.,* (2012) did not focused on economic efficiency of OFSP vine production, and hence this current study.

The objective of this study therefore was to measure the level of economic efficiency and its determinants in orange-fleshed sweetpotato vine production in North Central, Nigeria using the stochastic frontier translog cost function approach. This approach combines the concepts of technical and allocative efficiency in cost relationship. Technical and allocative efficiencies are necessary and when they occur together, are sufficient conditions for achieving economic efficiency (Yokopoulous and Lau, 1977). Economic efficiency is the ability of a farm-firm to produce a given level of output with the lowest amount of resources (Adeniji, 1988)

2. Material and Methods

2.1 Theoretical model

The stochastic frontier cost function of the i^{th} firm is defined by:

$$C_i = f(y_i, p_i, \alpha) + \varepsilon_i \quad (1)$$

Where:

C_i= represent the total input cost of the ith farms

f = is a suitable functional form (in this case translog)

y_i= Vine output produced in kg

p_i = Vector of input prices employed by the i^{th} farm

α = parameters to be estimated

ε_i = Composed random error terms ($v_i + u_i$)

The economically efficient (cost minimising) input vector, X_i^E , is derived by using Sheppard's Lemma and substituting the firm's input prices and adjusted output quantity into the system of demand equations (Bravo-Ureta and Pinheiro, 1997):

$$\frac{dC}{dp_i} = X_i^E (W_i, Y_i^*, \alpha) \quad (2)$$

For a given level of output, the corresponding, economically efficient and actual costs of production are equal to $W_i X_i^E$, and $W_i X_i$ respectively. These two cost measures are then used as basis for calculating the economic efficiency indices for the i^{th} firm:

$$EE_i = \frac{W_i X_i^E}{W_i X_i} \quad (3)$$

2.2 Empirical model

In this study, the stochastic frontier translog cost function was estimated for orange-fleshed sweetpotato vine entrepreneurs using the maximum likelihood method and the model is specified as:

$$\begin{aligned} \text{In}C_i = {} & \alpha_0 + \alpha_1 InP_1 + \alpha_2 InP_2 + \alpha_3 InP_3 + \alpha_4 InP_4 + \alpha_5 InP_5 + \alpha_6 InP_6 + \alpha_7 InY^*{}_7 + 0.5\alpha_8 InP_1^2 \\ & 0.5\alpha_9 InP_2^2 + 0.5\alpha_{10} InP_3^2 + 0.5\alpha_{11} InP_4^2 + 0.5\alpha_{12} InP_5^2 + 0.5\alpha_{13} InP_6^2 + 0.5\alpha_{14} InY^{*2}_7 + \alpha_{15} InP_1 InP_2 + \alpha_{16} InP_1 InP_3 + \\ & \alpha_{17} InP_1 InP_4 + \alpha_{18} InP_1 InP_5 + \alpha_{19} InP_1 InP_6 + \alpha_{20} InP_1 InY^*{}_7 + \alpha_{21} InP_2 InP_3 + \alpha_{22} InP_2 InP_4 + \alpha_{23} InP_2 InP_5 + \\ & \alpha_{24} InP_2 InP_6 + \alpha_{25} InP_2 InY^*{}_7 + \alpha_{26} InP_3 InP_4 + \alpha_{27} InP_3 InP_5 + \alpha_{28} InP_3 InP_6 + \alpha_{29} InP_3 InY^*{}_7 + \alpha_{30} InP_4 InP_5 + \\ & \alpha_{31} InP_4 InP_6 + \alpha_{32} InP_4 InY^*{}_7 + \alpha_{33} InP_5 InP_6 + \alpha_{34} InP_5 InY^*{}_7 + \alpha_{35} InP_6 InY^*{}_7 + V_i + U_i \end{aligned} \quad (4)$$

Where C_i represents total input cost of i^{th} farm, P_1 is land rent in naira per hectare, P_2 is price of planting material in naira per bundle, P_3 is price of fertilizer in naira per kg, P_4 is price of transport in naira, Y is output of OFSP vine in Naira adjusted for statistical noise, P_5 is depreciation of farm assets in naira, P_6 is average daily wage per man-day, α_0 , α_1, α_2 , …, α_{35} are regression parameters to be estimated, while V_i and U_i are as defined earlier.

The transcendental logarithmic functional form using the stochastic frontier cost function model was used to estimate the economic efficiency of orange-fleshed sweetpotato vine entrepreneurs. The economic efficiency model was estimated using the computer programme, FRONTIER version 4.1 (Coelli, 1996) and the programme was implemented with STATA version 10.0. The programme gives the maximum likelihood estimates of the parameters of the model. The economic efficiency measure takes a value between zero and one, with the value of one indicating full efficiency. The determinant of economic efficiency was estimated by using ordinary least squares regression technique.

2.3 Determinants of Economic Efficiency

The determinants of economic efficiency of OFSP vine entrepreneurs were modeled in terms of socio-economic variables and farm specific factors. Following Battese and Coelli (1995), the determinants of economic efficiency model was simultaneously estimated with Exp ($-\mu_i$) defined by:

$$\text{Exp}(-\mu_i) = \delta_0 + \delta_1 z_1 + \delta_2 z_2 + \delta_3 z_3 + \delta_4 z_4 + \delta_5 z_5 + \delta_6 z_6 + \delta_7 z_7 + \delta_8 z_8 + \delta_9 z_{9+} \delta_{10} z_{10} \quad (5)$$

Where Exp($-\mu_i$) is the economic efficiency of the i_{th} OFSP vine entrepreneur, Z_1 is the age of the vine entrepreneur in years, Z_2 is gender, a dummy variable, 1 for male and 0 for female, Z_3 is vine entrepreneurs level of education in years, Z_4 is household size in number, Z_5 is farm experience of vine entrepreneur in years, Z_6 is access to credit, a dummy variable, 1 for access and 0 for no access, Z_7 is number of times visited by an extension agent per farming year, Z_8 is membership of cooperative societies, a dummy variable, 1 for member and 0 for non member, Z_9 is production system, a dummy variable, 1 for sole cropping and 0 for mixed cropping, Z_{10} is farm size in hectares, while $\delta_0,\ldots,\delta_{10}$ are regression parameters to be estimated.

2.4 Data

The study was conducted in the North Central geo-political zone of Nigeria. The geo-political zone comprises six states, namely: Benue, Kogi, Nasarawa, Plateau, Kwara and Niger. This geo-political zone was chosen based on the intensity of orange-fleshed sweetpotato vine production.

Multistage sampling procedure was employed to select the respondents in this study. The first stage involved the purposely selection of three states out of six states in the North central based on their distinct OFSP production (National Root Crops Research Institute, NRCRI, 2012). The three selected states were Benue, Nasarawa and Kwara. The second stage involved the purposely selection of Local Government Areas (LGAs) from the three selected states based on the intensity of OFSP vine production. Thus, in the second stage, Gboko, Konshisha, Vandeikya, Kwande and Makurdi were selected from Benue state while Karu, Lafia, Keffi, and JDA were selected from Nasarawa state. Edu, Ifelodun, and Patigi, were selected from Kwara state. The third stage involved the random selection of 139 (consisted of 130 vine entrepreneurs from Benue, 5 from Nasarawa and 4 from Kwara states) farm households from the selected local government areas based on sampling frame from the respective ADPs for the analysis of economic efficiency in OFSP production. Data were collected with aid of structured questionnaire designed for a single visit.

3. Results and Discussion

Estimation of economic efficiency is presented in Table 1. The result in Table shows the maximum likelihood estimates of the translog stochastic cost function for orange-fleshed sweetpotato vine entrepreneurs North central, Nigeria. The sigma square (σ^2) is 2.7218 and the gamma (γ) is 0.9733 which are quite high and significant at 1.0% level of probability. The high and significant value of the sigma square (σ^2) indicates the goodness of fit and the correctness of the specified assumption of the composite error term distribution (Okoye and Onyeweaku, 2007). The gamma (γ) shows that 97 percent variation in the total OFSP vine production cost is due to differences in their cost efficiencies.

The coefficients of the explanatory variables have desired positive sign which are agrees with *a priori* expectations. The implication is that 1% increase in land rent, price of planting material, wage rate, price of fertilizer, price of herbicide and depreciation would lead to increase in total cost of OFSP vine production by 25.88, 17.27, 11.67, 2.17, 4.06 and 8.12 percent respectively. The high values of these coefficients indicate the significance of the variables cost structure of OFSP vine farm business. This result is consistent with the finding of Okoye and Onyenweaku, (2007).

Most of the interaction terms (2nd order coefficients) were statistically significant at the conventional significance levels, implying the suitability of the translog function (Okoye and Onyenweaku, 2007). For example, the coefficients of the square term for land rent, price of planting material and the interactions of land and output, price of pesticide and depreciation, depreciation and output are positively and highly significant at 1.0% levels of probability, indicating a direct relationship with total cost of OFSP vine production. The coefficients of square term for price of fertilizer, depreciation and interaction between wage rate and output are significant at 5% level of probability and which indicates a direct relationship.

Table 1. Maximum Likelihood Estimates of the Translog Stochastic Cost Function for Orange-Fleshed Sweetpotato Vine Entrepreneurs

Production factor	**Parameter**	**Coefficient**	**Standard Error**	**t-value**
Constant Term	α_0	5.1675	0.9632	5.3651***
Land rent	α_1	25.8770	2.5613	10.1031***
Price of planting material	α_2	17.2722	2.3165	7.4562***
Wage rate	α_3	11.6748	4.936	2.3652**
Price of Fertilizer	α_4	2.1709	0.8965	2.4216***
Price of pesticide	α_5	4.0605	1.1165	3.6372***
Depreciation	α_6	8.1179	0.8426	9.6344***
Output (y*)	α_7	2.8166	0.7986	3.5277***
Land rent^2	α_8	6.8535	1.8967	2.6134***
Price of planting materials^2	α_9	0.2997	0.1110	2.7003***
Wage rate^2	α_{10}	-1.5360	0.3917	-3.9214***
Price of agro fertilizer^2	α_{11}	1.1505	0.4746	2.3263**
Price of pesticides^2	α_{12}	0.1182	0.6237	0.1896
Depreciation	α_{13}	0.5271	0.2456	2.1463**
Output^2 (y*)	α_{14}	0.7639	0.8367	0.9131
Land rent x price of planting material	α_{15}	-0.5301	0.0943	-5.6216***
Land rent x wage rate	α_{16}	-0.338	0.3621	-0.8613
Land rent x price of fertilizer	α_{17}	-0.7036	0.1997	-3.5236***
Land rent x pesticide	α_{18}	1.3815	0.4326	3.1938***
Land rent x Depreciation	α_{19}	0.4667	0.0456	10.2367***
Land rent x output (y*)	α_{20}	0.2989	0.6001	0.4982
Price of planting material x wage rate	α_{21}	-0.11345	0.0923	-1.4568*
Price of planting material x price of Fertilizer	α_{22}	0.4447	0.3217	1.3824*
Price of planting material x price of Pesticides	α_{23}	-0.1956	0.3162	-0.6189
Price of planting material x Depreciation	α_{24}	-1.9004	3.6317	-0.5233
Price of planting material x Output (y*)	α_{25}	2.7505	1.4316	1.9213**
Wage rate x price of fertilizer	α_{26}	0.448	0.4926	0.8361
Wage rate x pesticide	α_{27}	-0.1310	0.3997	-0.3278
Wage rate x Depreciation	α_{28}	1.4044	0.2426	5.7892***
Wage rate x Output (y*)	α_{29}	0.5658	0.2532	2.2349**
Price of fertilizer x pesticide	α_{30}	-0.1795	0.4156	-0.4319
Price of fertilizer x Depreciation	α_{31}	-0.2200	0.4181	-0.5263
Price of fertilizer x output (y*)	α_{32}	0.6716	0.2385	2.8163***
Price of Pesticides x Depreciation	α_{33}	0.1005	0.0417	2.4106**
Price of Pesticides x Output (y*)	α_{34}	2.4255	0.3837	6.3214***
Depreciation x Output (y*)	α_{35}	0.0434	0.1361	0.3196
Diagnostic statistics				
Log-likelihood function		33.8867		
Sigma Square	σ^2	2.7218	0.1701	16.0014***
Gamma	γ	0.9738	0.2851	3.4141***

Table 2. Frequency Distribution of Efficiency Estimates of Orange-Fleshed Sweetpotato Vine Entrepreneurs

Economic Efficiency indices	Frequency	Percentage (%)
≤0.50	6	4.32
0.51-0.60	20	14.39
0.61-0.70	64	46.04
0.71-0.80	22	15.83
0.81-0.90	18	12.95
0.91-1.00	9	6.47
Total	139	100
Mean Economic Efficiency	0.60	
Minimum Economic Efficiency	0.26	
Maximum Economic Efficiency	0.92	

Table 3. Maximum Likelihood Estimates of the Determinants of Economic Efficiency of Orange-Fleshed Sweetpotato Vine Production

Efficiency factors	Parameter	Coefficient	Standard error	t-value
Constant term	z_0	-12.1933	0.5263	-23.1681***
Age	z_1	0.2428	0.0237	10.2463***
Education	z_2	0.2563	0.0527	4.8637***
Gender	z_3	-0.0622	0.0426	1.4618*
Farm experience	z_4	0.2918	0.0522	5.5913***
Extension visit	z_5	0.3548	0.0527	6.7342***
Access to credit	z_6	1.0173	0.4336	2.3463**
Membership of cooperative	z_7	0.3402	0.3928	0.8662
Household size	z_8	-1.5033	0.3459	-4.3262***
Production system	z_9	4.6313	0.8361	5.5392***
Off Farm Income	z_{10}	-0.1927	0.5123	-0.3762

The results of the frequency distribution of economic efficiency estimates are presented in Table 2. The result shows that the economic efficiency scores from the translog model ranges from 0.26 to 0.92 with a mean of 0.60. The estimates show that for the average OFSP vine entrepreneur to attain the efficiency level of most economically efficient vine entrepreneur in the North central, Nigeria, he or she would experience a cost savings of 34.78 percent (1- [0.60/0.92]100).

The least economically efficient vine entrepreneur will have an efficiency gain of about 72 percent (1- [0.26/0.92]100) in OFSP vine production if he or she is to attain the efficiency of the most economically efficient vine entrepreneur in the study area. The OFSP vine entrepreneurs in the sample were economically inefficient.

3.1 Sources of Economic Efficiency

The result in Table 3 shows factors influencing economic efficiency of OFSP vine entrepreneurs in North central, Nigeria. The sign of the coefficient of variables in the efficiency model is significant in explaining the observed economic efficiency of the OFSP vine entrepreneurs. A positive sign on the coefficient implies that the variable had an effect in increasing economic efficiency, while a negative coefficient implies reducing economic efficiency. The results shows that the coefficient of age, education, farm experience, extension visits, access to credit, membership of cooperative societies and production system were positive. The coefficient of age, education, farm experience, extension visit, household size and production system are significant at 1.0% level of probability. This suggests that age, education, farm experience, extension visit, access to credit and production system have positive influence on economic efficiency among the OFSP vine entrepreneurs in the study area. This result is consistent with finding of Gbigbi (2011).

The coefficient of gender is negative and significant at 10 % probability level. The negative coefficient of gender implies that male headed households in the study area are relatively more economically inefficient than their female counterparts. This signals that OFSP vine production is women's business and is consist with long held view that sweetpotato production in general, is women's affair. Household size has a negative coefficient and is highly significant at 1 % level of probability. Effiong (2005); Idiong (2005); Coelli et al (2002) and Mariano *et al.,* (2010) they severally reported that relatively large household sizes enhance availability of farm labour though large household sizes may not guarantee for increased efficiency since family labour consists of mostly children of school age are often in schools.

The coefficient of gender is negative and significant only at 10% level of probability. The coefficient of age is positive and significant at 1 % level of probability implying that OFSP vine entrepreneurs' who are advanced in age and have attain high level of education, farm experience, extension visit, access to credit, and are practicing sole cropping system are more economically efficient.

4. Conclusion

The study showed that OFSP vine production system was not fully economically efficient. Individual economic efficiency of OFSP vine entrepreneurs' ranges between 0.26-0.0.92 with a mean of 0.60 which reveals substantial economic inefficiencies in the system, thus considerable room for increasing profitability required reducing cost. For an average OFSP vine entrepreneur to be fully economic efficient, he or she would be able to reduce cost by 34.78 percent under the current technology.

The study revealed the important factors directly related to economic efficiency as age, education, farm experience, extension visit, access to credit and production system. These results call for policy decisions that would encourage new entrepreneurs to take up OFSP vine production through enhanced access to education, extension services and credit. Follow up studies are required to determine the economic efficiency and its determinants in different geo-political zones using panel data.

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