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Technical, Economic and Allocative Efficiencies of Pepper Production in South-West Nigeria: A Stochastic Frontier Approach

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Abstract

Despite increases in the cultivation of pepper among farmers in South-West Nigeria, massive transportation of pepper from the Northern parts of the country and seasonal fluctuation in prices are still very common. Given a good knowledge of the efficiency levels of various production units (farms), output can be increased in the short-term by improving production efficiency. This study examined technical, allocative and economic efficiencies in pepper production in south-west Nigeria. Data were collected from three hundred pepper farmers who were sampled through a multi-stage sampling procedure. Data were analyzed using the stochastic frontier approach. The results revealed average technical, allocative and economic efficiencies of 0.737, 0.893 and 0.658 respectively. These imply that given the present efficiencies levels, there is room for the average farmer to increase pepper output or save costs without the need to change existing technology. Extension contact, gender, indigeneship status, age and household size have significant effect on technical inefficiency. The study recommended among others, intensive extension services which focus more on native, older and female farmers and are geared towards raising technical knowledge of pepper farmers in order to improve output significantly.

Key words: Pepper, Technical efficiency, Economic efficiency, Allocative efficiency

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Introduction

Pepper is one of the most varied and widely used foods in the world. Virtually all countries of the world produce pepper at different levels. According to Boseland and Votava (2000), pepper production has increased in recent years worldwide and this could be ascribed partly to its high nutritional value. Pepper is a rich source of vitamins A and E and contains more vitamin C to prevent flu-colds than any other vegetable crop. In Nigeria, three major types of peppers are common. The large fruited sweet pepper (*tatashe*), the medium corrugated fruited hot pepper (*rodo*) and the small fruited chilli/red pepper (*shombo*) (Ado, 1990). In Nigeria, nearly all meals prepared at household level contain some fractions of pepper hence the importance of pepper in the meal of an average Nigerian. Pepper is produced in larger quantities in the northern part of the country and the north supplies the bulk of the pepper needs of the southern parts whose production is still at small scale. Despite increasing cultivation of pepper in the south-western part of the country seasonal price fluctuation and scarcity is still common.

Studies on the productivity and efficiency of agricultural production in Nigeria have not focused on pepper despite its important role in the meal of the people. In order to achieve self-sufficiency in pepper production in the south-western part of the country, there is an urgent need to assess the efficiency of production in pepper farming. According to Belbase and Grabowski (1985) an important policy implication stemming from significant level of inefficiency is that it might be more cost effective to achieve short term increases in farm output, and thus income by concentrating on improving efficiency rather than on the introduction of new technology. This study determined the efficiency levels of pepper farmers and identified socioeconomic factors affecting efficiency levels. This is expected to identify issues which are germane to formulating policies aimed at increasing pepper production at least in the region.

2. Theoretical framework

The earliest of the efficiency theories is the production theory and the concept of isoquants centers on the relationships between input and output. The isoquants represent the boundaries of inputs sets while the production possibility curves (frontiers) are the boundary of the outputs sets. The output and input function are often used to characterize the production function. This serves as basis for Technical Efficiency (TE) measurement. The production function has been extended over the years to accommodate different circumstances (Aigner *et al.*, 1977, and Meeusen and van den Broeck, 1977, Jondrow *et al.*, 1982 and Battese and Coelli, 1992).

Modern study of efficiency can be traced to Farrel (1957) paper on efficiency which introduced a methodology to measure economic, technical, and allocative efficiency. In this methodology, Economic Efficiency *(EE)* is equal to the product of Technical Efficiency (TE) and Alloactive Efficiency (AE). According to Farrell, TE is associated with the ability to produce on the frontier isoquant, while AE refers to the ability to produce at a given level of output using the cost-minimizing input ratios. EE is defined as the capacity of a firm to produce a predetermined quantity of output at minimum cost for a given level of technology (Kopp and Diewert 1982).

According to Ogundari (2007), an input-oriented approach to measure EE yields three sets of inputs: (1) the observed set, X_o, (2) the technically efficient set, X_{te}, and (3) economically efficient set X_{ee}. The gross products of these inputs sets the price vector which yields the costs of the observed technically efficient and economically efficient input set respectively. These costs can be used to devise measures of TE_i, AE_i and EE_i as shown hereby:

$TE_i = PX_{te}/PX_o$ ………………….(1)
$EE_i = PX_{ee}/PX_o$ …………………(2)
$AE_i = PX_{ee}/PX_{te}$ (i.e.,EE/TE)… (3)

Where PX_{te} and PX_{ee} are corresponding technically and economically efficient cost of production respectively while PX_o is the actual cost of production for any particular firm's observed level of output.

Aigner *et al.,* (1977), Meeusen and Van de Broeck (1977) and Battese and Corra (1977) independently developed the stochastic frontier production function to provide basis for estimating productive efficiency of firms. Their model can be summarized as:

$$y = f(X;\ \beta) + \varepsilon \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where y is scalar output, X is a vector of inputs and β is a vector of technology parameters. Here ε = v-u which is the decomposed error term (Aigner *et al.*, 1977). The two components v and u are assumed to be independent of each other, where v is the two-sided normally distributed random error ($v_i \sim N(0,\sigma_v^2)$, and u is one-sided efficiency component with a half-normal distribution ($u_i \sim N(0,\sigma_u^2)$. The Maximum Likelihood Estimation (MLE) of (equation 4) yields estimates for β and λ. Jondrow *et al.*, (1982) have demonstrated that the farm specific measure of technical inefficiency can be determined from the conditional expectation of u_i given as:

$$E(U_i|\varepsilon_i) = \frac{\sigma_u\sigma_v}{\sigma}\left[\frac{f(\varepsilon_i\lambda/\sigma)}{1-f(\varepsilon_i\lambda/\sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \ \ldots. (5)$$

here $\lambda=\sigma_u/\sigma_v$, $\sigma^2=\sigma^2_u+\sigma^2_v$, while *f* and F represents the standard normal density and cumulative distribution function respectively evaluated at $\varepsilon_i\lambda/\sigma$. Battese and Corra (1977) defined $\gamma=\sigma_u^2/\sigma^2$ such that $0\le\gamma\le1$ and represent the total variation in output from the frontier attributable to differences inefficiency.
The farm specific technical efficiency is defined in terms of observed output (Y_i) to the corresponding frontier output (Y_i*) using the available technology derived from the result of equation (5) above as:

$$TE = \frac{Y_i}{Y_i *} = \frac{E(Y_i \mid u_i, X_i)}{E(Y_i \mid u_i = 0, X_i)} = E\left[\exp(-Ui/\varepsilon)\right] \ \ldots\ldots (6)$$

Therefore, TE=exp(-U_i)TE takes values within the interval zero and one where 1 indicates a fully efficient farm.

According to Bravo-Ureta and Pinhero (1997), assume that the production frontier in equation (4) is self-dual (e.g. Cobb-Douglass) and that the corresponding cost frontier can be expressed as:

$$C = h(P,\ Y;\ \alpha) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

where *C* is the minimum cost to produce output *Y*, *P* is a vector of input prices, and α is a vector of parameters. Applying Shephard's lemma, the system of minimum cost input demand equations can be obtained by differentiating the cost frontier with respect to each input price. This demand equation for the *i*th input (*Xdi*) is equal to::

$$\delta C/\delta Pi = Xdi = f(P,\ Y;\ \Psi),\ \ldots\ldots\ldots\ldots(8)$$

where Ψ is a vector of parameters. From the input demand equations we can obtain the economically efficient input quantities, X_{ie}, by substituting the firm's input prices *P* and output quantity *Y* into equation (8).

Furthermore, the farm specific EE is defined as the ratio of minimum observed total production cost (C*) to actual total production cost (C) using the result of equation 5 above. That is:

$$EE = \frac{C_i}{C_i *} = \frac{E(C_i \mid u_i = 0, Y_i P_i)}{E(Y_i \mid u_i, Y_i P)} = E\left[\exp(-Ui \mid \varepsilon)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (9)$$

Here EE takes values between 0and 1. Hence, a measure of farm specific AE is thus obtained from technical and economic efficiencies estimated as:

$$AE = \frac{EE}{TE} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

3. Methodology

3.1 Study area

The study was carried out in Odeda and Obafemi/Owode Local Government Areas of Ogun State, South-West Nigeria. The state which is located in the South-West corner of the country lies within latitudes $3^0$30'N - $4^0$30'N and longitudes $6^0$30'E-$7^0$30'E and covers a land area of 16,762 square kilometers with a population of 3,728,098 (2006 population census). The people of the state are predominant of Yoruba tribe and at least 35percent of the populace are peasant farmers.

3.2. Data

Pepper farmers were sampled through a multi-stage sampling procedure. Two Local Governments (Obafemi-Owode and Odeda) were randomly selected from seven Local Government Areas noted for pepper production in the state. Villages and farmers were randomly selected from the official list of the State Agricultural Development Project. Farmers in these areas mostly cultivate the medium corrugated fruited hot pepper (*rodo*). A total of 300 farmers were sampled but 284 were used for analyses as others were discarded due to incomplete data. Relevant data were collected using structured questionnaire and data were collected on socioeconomic characteristics of pepper farmers such as age, educational level, household size, years of pepper farming experience, extension contact, access to credit, inputs, output, prices including other data of interest.

3.3. Empirical model

The econometric specification in this study follows the Cobb-Douglas functional form because of its wide application in farm efficiency for the developing and developed countries. For the pepper farmers in the study area, the specification is:

$$\text{In}Y_i = \beta_0 + \beta_1 \text{In}X_{1i} + \ldots\ldots\ldots\ldots + \beta_6 \text{In}X_{6i} + V_i - U_i \ldots (11)$$

Where: Y = Output of pepper for the entire season (kg)

X_1 = Farm Size in hectares

X_2 = Family labour in workdays

X_3 = Hired labour in workdays

X_4 = Pepper Seedling (in number of bundles used. A bundle is about 60 stands)

X_5 = Fertilizer in Kg

X_6 =Pesticides in litres

Vi and Ui are as described earlier.

The inefficiency model is specified thus:

$$\mu = \delta_0 + \delta_1 W_1 + \delta_2 W_2 + \delta_3 W_3 + \ldots z + \delta_8 W_8 \ldots\ldots\ldots(12)$$

Where, W_1 = Age of farmer in years

W_2 = Educational level of farmer (number of years spent in school)

W_3 = Household Size

W_4 = Years of Rice farming experience

W_5 = Extension contact (1 if the farmer has extension contact, 0 if otherwise)

W_6 = Access to credit (1 if farmer has access to credit, 0 if otherwise)

W_7 = Gender of farmer (1 if male, 0 if otherwise)

W_8 = Indigeneship status (1 if farmer is an indigene, 0 if otherwise)

Cobb-Douglas cost frontier function for pepper farms in the study area was specified as:

$$InCi = \alpha_0 + \alpha_1 InP_{1i} + \alpha_2 InP_{2i} + \alpha_4 InP_{4i} + \alpha_5 InP_{5i} + V_i + U_i \quad \ldots\ldots\ldots\ldots (13)$$

Here C is total production cost of pepper per farmer for the season; P_1 is the rental value of land per hectare for the season, P_2 is the wage rate of labour/ workday, P_3 is the price of seedling/ bundle; P_4 is the price of fertilizer / kg; P_5 is the price of pesticide / litre; α_s were parameters estimated. The frontier cost function was estimated using MLE methods. The computer programme FRONTIER version 4.1 was used and it should be noted that this programme estimates the cost efficiency (CE), which is computed originally as the inverse of equation (9). Hence, farm–level EE was obtained using the relationship:

$$EE = 1/CE \quad \text{(Coelli } et\ al.\text{, 1998)} \quad \ldots\ldots\ldots(14)$$

4. Results and discussion

The mean age of pepper farmers in the study area was 47years mostly educated up to primary school level. The average pepper farmer cultivated a farm size of 0.75ha, utilized 72man-days of labour, 93.5kg of fertilizer and 3.49litres of insecticides and realized an output of 1015.6kg of pepper. Table 1 shows the summary statistics of technical inputs and some socioeconomic variables of pepper farmers in the study area.

Table 1: Summary statistics of variables in the production function

Variables	Mean	Minimum	Maximum	Standard Deviation
Output (Kg)	1015.6	309.5	1402	261.3
Hired Labour	32.7	11	97	23.7
Family Labour	40.1	10	116	47.1
Household Size	7	1	12	1.9
Experience (years)	11.6	1	30	4.5
Farm Size (ha)	0.75ha	0.20	2.80	0.45
Fertilizer (kg)	93.5	12	450	75.6
Seedling bundles	57	6	117	45.8
Pesticide (litre)	3.49	0.2	10.4	3.6
Age of farmer (yrs)	47.1	25	65	12.2
Education (yrs)	6	0	12	5

4.1. Results of the stochastic production and cost functions

The results of the Maximum Likelihood Estimation of the production function (Table 2) revealed that all the explanatory variables have positive effect on pepper output except family labour. It was further shown that farm size, seedling bundles, fertilizer and pesticides significantly affect the quantity of pepper produced by the farmers. Farm size and fertilizer were significant at 5percent α-level while seedling and pesticide were significant at 10percent α-level. The non-significance of labour, though very rare, is in line with Kaine (2011) finding in a study of technical efficiency of Akpu processors in Delta State, south-south Nigeria. The gamma value of 0.998 which was significant at 1percent means that inefficient effect existed in pepper production in the study area. The Return to Scale value obtained by the summation of the estimated coefficients of the production function value of 0.938 means that farmers are operating in stage II of the production surface. This is a stage of positive diminishing return to scale and it is the stage of production for rational producers. In this stage, resources and production were believed to be efficient. Hence, it is advisable that the production units should maintain the level of input utilization at this stage as this will ensure maximum output from a given level of input *ceteris paribus*.

The inefficiency model included in the stochastic production function (Table 2) shows that age of farmers, household size; extension contact, gender and indigeneship status significantly affect efficiency. The positive sign of age implies that increases in age cause increase in inefficiency (reduction in technical efficiency). The implication is that older farmers may tend to be less technically efficient when compared with other farmers. There were significant and negative signs of household size, extension contact, gender and Indigeneship status. The implications is that farmers with large household size were more technically efficient than farmers with fewer people in their households perhaps due to the fact that large household size serves as a readily available source of labour for the farmers given the labour intensive nature of pepper farm maintenance and frequency of harvesting. Farmers who claimed to have frequent contact with extension agents tend to be more technically efficient than those who claimed otherwise underscoring the importance of extension training in pepper farming. Furthermore, male farmers were more efficient than female farmers and farmers who were immigrants in the study areas were generally more efficient than indigenes (it should be recalled that indigenes were scored one while none indigenes were scored zero in the quantification of the dummy variable "indigeneship"). This may be due to large household size kept by majority of the immigrant farmers who are mostly *Igedes* from Benue state.

Bashin (2002) reported that farmer's level of education, the distance of farms to the market and extension services have significant positive effect on the technical efficiency of green pepper farmers in the Upper East Region of Ghana. It was further reported that the age of the farmer, his level of education, distance of the farm to farmer's house and methods applied to increase productivity of the land were effective in terms of tomato efficiency. For onion production, it was reported that farming experience, distance to market and extension services had significant positive effect on technical efficiency.

The significant positive effect of age and household size on technical inefficiency in this study is in line with the findings of Ajibefun (2002). The study reported a mean technical efficiency of 0.63 (which is lower than 0.737 reported in this study) while education and experience have significant negative effect on technical inefficiency. Ogundari and Ojo (2007) reported significant negative relationship between age, education, farming experience and credit availability and technical inefficiency among small scale crop farmers in Ondo state Nigeria.

The result of the stochastic cost function (Table 3) revealed that all the explanatory variables carried positive values in conformity with the *a priori* expectation. Rental value of land, wage and price of seedlings were significant at 1percent α-level while prices of fertilizer and pesticide were not significant. This implies that significant increases in the prices which were significant increase cost of production significantly while changes in the prices of fertilizer and pesticide did not significantly increase total cost of production. This insignificance may be due to the low level of use of the two inputs (Table 2).

4.2. Distribution of efficiencies among pepper farmers

The MLE estimations of equation (11) also revealed an average TE of 73.7 percent and using the relationships in equations 9,10 and 14, it was also shown that the average AE and EE were 89.3 and 65.8percents respectively. These imply that increases in output can be achieved if certain corrective measures (such as intensification of extension

Table 2: Production function parameter estimates for pepper farms

Variable	**Parameter**	**Coefficient**	**t-ratio**
Constant	β_0	2.891***	2.65
Farm size	β_1	0.052**	2.33
Family labour	β_2	-0.024	-0.51
Hired labour	β_3	0.057	1.09
Seed	β_4	0.257*	1.84
Fertilizer	β_5	0.375***	2.82
Insecticide	β_6	0.221*	1.71
Inefficiency model			
Age	δ_1	0.490***	3.022
Education	δ_3	0.590	0.029
Household size	δ_4	-0.291**	-2.282
Experience	δ_5	-0.028	-0.719
Ext. contact (=1)	δ_6	-2.109*	-1.763
Credit (Access=1)	δ_7	1.015	1.331
Gender (male=1)	δ_8	-2.014*	1.942
Indigeneship (=1)	δ_9	3.162***	2.927
Sigma-squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.617***	5.665
Gamma	$\gamma = \sigma_u^2 / \sigma^2$	0.956***	4.651
Log Likelihood function	LLF	11.9	

**** Significant at 1percent; ** Significant at 5percent; *Significant at 10percent*

Table 3: Cost function parameter estimates for pepper farms

Variable	Parameter	Coefficient	t-ratio
Constant	α_0	3.814**	2.54
Land price	α_1	0.253***	2.60
Labour price	α_2	0.0035***	3.17
Seedling price	α_3	0.762***	2.64
Fertilizer price	α_5	0.039	0.30
Insecticide price	α_6	0.003	0.39
Sigma-squared	σ^2	0.146***	5.71
Gamma	γ	0.880***	13.14

Table 4: Efficiency distribution of pepper farmers

Efficiencies	Technical frequency	Percent	Economic frequency	Percent	Allocative frequency	Percent
≤0.20	2	0.7	3	1.0	-	-
0.201-0.300	10	3.5	15	5.3	-	-
0.301- 0.400	17	6.0	38	13.4	-	-
0.401–0.500	31	10.9	48	16.9	8	2.8
0.501–0.600	54	19.0	53	18.7	30	10.6
0.601–0.700	62	21.8	79	27.8	51	18.0
0.701–0.800	76	26.8	34	12.0	65	22.9
0.801–0.900	27	9.5	14	4.9	94	33.1
> 0.900	5	1.8	-	-	36	12.7
Mean	0.737		0.658		0.893	
Minimum	0.171		0.159		0.481	
Maximum	0.916		0.817		0.954	

efforts) are taken without the need to change existing technology. Furthermore, if an average farmer was to achieve the TE of his most efficient counterpart, he could realize 19.5percent cost saving (i.e. 1 – (0.737/0.916) or increase in output. Table 4 shows the distribution of pepper farmers by various efficiency measures

4.3. Estimation of the determinants of allocative and economic efficiencies

As efficiency generally ranges between certain limits (i.e zero and one), factors affecting allocative and economic efficiencies were determined using the Tobit model as used by Bravo-Ureta and Pinheiro (1997), and Akinbode (2010).

The results of the maximum likelihood estimation of the tobit model (Table 5) revealed that Education (α=0.01) and extension contact (α=0.01) have significant positive effect on Allocative Efficiency. This imply that more educated farmers and farmers who claimed to have frequent contact with extension agents have ability to allocate input bundle or produce a given level of output in the cost minimizing way. The negative but significant coefficient of gender (α=0.05) implies that female pepper farmers were more allocatively efficient than their male counterpart. The implication is that female farmers take better decisions in relation to input price differences and quantity to be utilized on the farm.

Furthermore, the Tobit model estimation revealed that only education (α=0.01) and extension contact (α=0.05) have significant effect on the overall economic efficiency of pepper farmers in the study area. The positive signs of these significant variables implied that more educated and farmers who have contact with extension services were more capable of producing predetermined quantity of output at minimum cost for a given level of technology. Akinbode (2010) also reported that extension contact and education among other variables exert significant positive effects on both allocative and economic efficiencies among rice farmers Ogun State which included the study area selected for this study. Bravo-Ureta and Pinheiro (1997) in the same vein found that education had significant positive effect on allocative and economic efficiencies among peasant farmers in the Dominican Republic.

Table 5: Parameters estimates of determinants of allocative and economic efficiencies of pepper farmers

Variables	Economic coefficient	t-ratio	Allocative coefficient	t-ratio
Age	-1.178	-1.490	-0.591	-0.147
Education	0.177***	2.621	0.699***	2.824
Households size	0.691	0.652	1.103	0.039
Experience	-0.529	-1.361	-0.601	-1.327
Extension	1.271**	2.11	2.096***	2.019
Credit	-1.084	-0.561	-0.099	-0.109
Gender	-0.052	-0.051	-1.534**	-3.213
Indigineship status	0.345	1.309	0.837	0.092
Log-likelihood function	27.43		38.17	
Sigma-squared	0.0016		0.0574	

**** Significant at 1percent; ** Significant at 5percent; *Significant at 10percent*

5. Summary and conclusion

The study assessed technical, allocative and economic efficiencies in pepper production in south-west Nigeria. The study revealed an average technical, allocative and economic efficiencies of 0.737, 0.893 and 0.658 respectively. It should be noted that it appeared that AE contribute more to gains in EE than TE. This means farmers generally take good decisions as relate to resource allocation in cost minimization strategies.

Meanwhile, decisions in the transformation of physical inputs to outputs appeared imperfect. Given the significance of extension contact as an important factor affecting the three types of efficiencies considered in this study, it is recommended intensive extension training which may improve technical knowledge of pepper farmers and possibly their price-quantity decision knowledge. The extension service should focus more on native, older and female farmers.

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