American Journal of Experimental Agriculture
2(4): 667-679, 2012

SCIENCEDOMAIN ***international***
www.sciencedomain.org

Economic Efficiency of Soybean Production in Ogo-Oluwa Local Government Area of Oyo State, Nigeria

A. O. Ajao[1], L. T. Ogunniyi[1*] and A. A. Adepoju[1]

[1]Department of Agricultural Economics, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author AOA designed the study, performed the statistical analysis, and contributed to the first draft of the manuscript. Authors LTO and AAA did the literature search, prepared the data for the analysis and managed the analyses of the study. All authors read and approved the final manuscript.

Research Article

Received 5th March 2012
Accepted 2nd November 2012
Published 17th November 2012

ABSTRACT

This study estimated the technical, allocative and economic efficiencies indices and further examined the factors influencing technical efficiency for the sampled soybean farms in Ogo-Oluwa Local Government Area of Oyo State (LGA). The study made use of a cross-sectional data obtained from sampled soybean farmers in the Ogo-Oluwa of Ogbomoso zone of Oyo State Agricultural Development Project (ADP) that were purposively selected because of the higher concentration of soybean farms compared to other LGAs in the zone. Eighty respondents were randomly chosen from a list of soybean farmers obtained from the Apex Farmers Association of Nigeria (AFAN). Data collected was analysed using the stochastic frontier model. The overall technical efficiency was estimated with no effort of broken it down into pure and scale efficiencies. It was observed from the findings that the range of efficiencies index varies great with minimum of 0.827, 0.135 and 0.128 and maximum of 1.0 for technical allocative and economic efficiencies respectively. The mean efficiency which indicate the average potential there in soybean production in the study area 0.94, 0.892 and 0.839 for technical, allocative and economic efficiency respectively. Of 80 soybean farmers involved in the analysis only one was found to be technically allocatively and economically efficient. The measures of relative allocative and technical efficiency provide evidence as to the source of deviations from overall cost-minimising

**Corresponding author: Email: ltogunniyi@lautech.edu.ng, titiogunniyi@yahoo.com;*

behaviour. Many sampled soybean farms employed the ‘wrong’ input mix, given input prices, so that, on average, costs were 11 per cent higher than the cost minimizing level. However, farms have the potential to reduce their physical input, on average, by 6 per cent, and still produce the same level of soybean output.
In conclusion, there was a great potential to improve the output of soybean farms and save cost if variable inputs were adjusted to the optimal level along the short-run isoquant. Farmer’s age, extension visit and education significantly influence technical, economic and allocative efficiencies respectively. Inefficiency results in large part from allocative rather than from technical inefficiency.

Keywords: Soybean; DEA; economic efficiency; Tobit.

1. INTRODUCTION

Soybean (*Glycine max*) is an arable crop which has been described as cheap source of protein, edible vegetable oil and good balance of amino acids. The soybean seed contains about 20% oil and 34-36% protein. These components determine the economic worth of soybean seed. It has a very high protein to improve the nutritional status of the families of the poor farmers because despite the advances in the world’s agriculture, most people mainly in Africa are still very undernourished.

Adequate food and proper nutrition are basic requirements for economic development, since an underfed nation is an under productive nation. Poverty and malnutrition often afflict the same beleaguered groups of people. Sometimes, rates of malnutrition are used as indicators of poverty. Studies by Haddad and Alderman (2000) reveal that more income leads to better nutrition over time. Inadequate protein in diet appears to be the greatest nutritional problem facing Nigerians today. This is because most sources of animal protein are expensive and only few people can afford enough of them in the diet. Also sharp increase in prices of animal products is now making an average Nigerian conscious of the fact that the grain legumes may provide a cheaper source of protein. Soybean (*Glycine max)* is one of the important grain legumes in the world in general and particularly in Nigeria. The crop is known for its high nutritive value. An earlier report (Food and Agriculture Organization, 1982) show that the protein content of soybean, which is about 40.0 percent of the seed weight, is higher than the protein content of any other crop. Although soybean is a plant protein source, it has a higher content of lysine, a sulphur containing amino acid. Soybean also contains about 20.0 percent of oil. Studies by Lassitar (1981) revealed that the oil is highly digestible, high in polyunsaturated fatty acids about 85.0 percent with no cholesterol. The studies also show that mature soybean seed contains vitamins such as thiamine, niacin, riboflavin, vitamin E and vitamin K. These vitamins are necessary for normal body growth and development. Soybean products serve as essential raw material for vegetable oil industries. An earlier report by Institute of Agricultural Research and Training, IAR and T (1987) reveal that soybean ranks the highest among leguminous crops in terms of protein utilization and efficient ratio compared with other plant sources. The report also reveals that soybean has a high total digestible nutrient percentage of 91.99 percent compared to cowpea with 79.52 percent. It consumption thus helps in solving nutrition protein-intake problem among the poor people. It is currently cultivated in all the major agro-ecological zones of Nigeria. Soybean is used for various cheap recipes.

Production efficiency means the attainment of production goals without waste. Efficiency is often used synonymously with that of productivity which relates output to input. In agriculture, the analysis of efficiency is generally associated with the possibility of farm production to attain optimal level of output from a given bundle of input at least cost. The crucial role of efficiency in increasing agricultural output has been widely recognized by researchers and policy makers alike. It is not surprising that considerable effort has been devoted to the analysis of farm level efficiency in developing countries including Nigeria. An underlining premises behind much of this work is that farmers are not making efficient use of existing technology, then efforts designed to improve efficiency would be more cost effective than introducing new technologies as a means of increasing agricultural output (Battese and Coelli, 1995).

There have been few studies on economics of soybean production in Nigeria e.g. Otitoju and Arene (2010) revealed the potential and constraints in soybean production in Benue state but falls short of providing the economic values of these potential, also Olorunsanya et al. (2009) attempted to address this using marginal values which we consider inadequate in view of its average value, In view of this the study examined the efficiency of soybean production in the selected area. The rest of this paper is structured as follows. Section 1 discusses the literature reviewed and the concept of efficiency while section 2 describes the source of data and gives basic information on the study area, it present the models used to examine the efficiency of soybean production. Section 3discusses the findings of the study putting into consideration the technical, economic and allocative efficiencies of production and cost minimizing input of soybean farms as well as correlation of the efficiencies examined. Section 4 concludes and gives recommendations of the study.

1.1 Overview of Literature

Whereas there exists a large body of empirical literature on economic efficiency of farmers in developed countries and Asian economics, only a few empirical studies have focused on African agriculture to measure technical efficiency. These have proceeded along two general approaches: non-parametric and parametric. Whereas the parametric impose a functional form on the production function and use the common production functions such as the Cobb-Douglas and trans log production functions, the non-parametric do not and use Linear Programming. Most parametric approaches adopt either the two-step or the one-step stochastic frontier approach first developed by Aigner et al. (1977) and Meeusen and Van den Broach (1977).

From the existing studies, a consensus that seems to emerge is that farmers are inefficient in their resource allocation. Between 18-30 percent of agricultural output is lost due to inefficiencies specific to the farms. Different studies have identified different sources of inefficiency but the most common are socio-economic variable such as farmers" age, level of education and experience, farm size, number of hired workers, distance between farms and the nearest city, years of faming experience, extension service visit, land ownership as well as membership of farmers cooperative among others. It has been argued that it is possible to increase agricultural production significantly by simply improving the producer's technical efficiency without additional investment.

Several authors' present strength and weaknesses of various techniques used in the efficiency measurement. For example, Coelli (1995) among others noted that the stochastic frontier model specification not only addressed the noise problem associated with earlier (deterministic) frontiers, but also permitted the estimation of standard error and test of hypotheses which were not possible with the earlier deterministic models because of the violation of certain maximum likelihood regularity conditions. However, it was further noted that there is a problem of no *a* priori justification for the selection of any particular distributional form. Though the specification of a more general distributional forms such as the truncated-normal (Stevenson, 1980) and the two parameter gamma (Greene, 1990) has partially alleviated this problem but the resulting efficiency measure may still be sensitive to distributional assumption. The need for imposing an explicit parametric form for the underlying technology and an explicit distributional assumption for the inefficiency term are the main weaknesses of the parametric approach.

According to Sharma et al.(1999), DEA avoids parametric specification of technology as well as distributional assumption for the inefficiency term. By using DEA one will be able to:

(i) Compare a group of service units to identify relatively inefficient units.
(ii) Measure the magnitude of the inefficiencies.
(iii) Compare the inefficient with the efficient ones.
(iv) Discover ways to reduce the inefficiency.

However, DEA is deterministic and attributes all deviations from the frontier to inefficiency; a frontier estimated by DEA is likely to be sensitive to measurement error or other noise in the data. Various authors have examined the empirical performances of these two approaches. For instance, Louisa et al. (1998) found out that overall distribution of the technical efficiency scores for the stochastic production frontier (SPF) and VRS DEA models were similar while the efficiency scores for individual boat varied considerably for these two approaches. Also, Sharma et al.(1999) found the result from the DEA to be more robust than those from the parametric.

This study demonstrates an approach to determining the farm efficiency using DEA technique. DEA is a non-parametric technique that measures the efficiency of Decision-Making Units (DMU) relative to production possibility or input requirement set. It was further described by Seiford and Thrall (1990) in terms of floating piece-wise linear surface to rest on top of the observations. Specifically, the key constructs of a DEA model are the envelopment surface and the efficient projection path to the envelopment surface (Charnes et al., 1985).

The envelopment surface and the efficient projection path depend on the scale assumption that underlined the model and the optimisation assumption respectively. The optimisation production process could be output or input-oriented model. The input-oriented model shows how much the input could be proportionally reduced without changing the quantity of the output produced while the output-oriented shows how much the output quantity could be proportionally expanded without altering the input quantity. Output-oriented model gives credence to neo-classical production function defined as the maximum output given input quantity (Fare et al.,1994).

Most DEA applications to efficiency measurement in the literature are input-based type. The few published applications of output-based efficiency have primarily focussed on the technical, scale and congestion efficiency (Fare et al., 1994). In this study, the input-oriented model approach was used to estimate various efficiency indices because farmers tend to have greater control over their inputs than over their output.

Non-parametric production frontier estimation was used in this study because it de-emphasises the assumptions that support much of the classical parametric production frontier and has the following merits as listed in the literature among which are:

(i) It requires less restrictive population assumptions than corresponding parametric methods.
(ii) It generates a single input/output index to characterise efficiency of a firm or decision-making unit producing multiple output from a set of inputs (Charnes et al., 1978).
(iii) It avoids parametric specification of technology.

1.2 The Concept of Efficiency

Efficiency is a very important factor in productivity growth especially in developing agricultural economies where resources are meager and opportunities for developing and adopting better technologies have lately been dwindling (Ali and Chaudhry, 1990). Farm efficiency can be measured in terms of technical, allocative and economic efficiency. Technical efficiency refers to the ability of a firm to achieve maximum possible output with available resources while allocative efficiency refers to the ability to contrive an optimal allocation of given resources. Economic efficiency is a product of technical and allocative efficiency (Farrell, 1957). One of the limitations of Farrell (1957) approach was an assumption of Constant Returns to Scale (CRS) which itself, was very restrictive.

This assumption implies that the scale of production does not affect the efficiency. Allowing technology rendering Variable Returns to Scale (VRS) opens the possibility that the scale of production could affect efficiency. If the technology of production process exhibits VRS, it is clear that some of the existing inefficiency could be due to sub-optimal scale. In that case, it would be necessary to distinguish between total efficiency and pure scale efficiency and this can be done by estimating the efficiency using both CRS and VRS assumption.

The difference between the efficiency measurement estimated under CRS and VRS assumptions is illustrated in Fig. 1. The Fig. is simplified by showing four firms producing one output (Y), using a single input (X). The point a_{crs} represents best practice reference technology based on CRS from the origin through C, while a frontier based on VRS technology goes through the points ACD. The Farrell distance measure for firm B, under VRS assumption, requires firm B to be compared against a VRS frontier. The point a_{vrs} on the frontier shows how much of input X that is strictly needed to produce the same amount output (Y), and serves as reference point for firm B. Total technical efficiency shows the relationship between maximum productivity and observed productivity. The point a_{crs} shows the necessary input usage if the firm was both technically efficient and operated at optimal scale. Under the constant returns to scale (CRS), the input oriented technical inefficiency at point B is the distance Ba_{crs}. However, variable returns to scale (VRS) technical inefficiency will be distance Ba_{vrs}. The difference between these technical efficiency measures is due to scale inefficiency. Thus, the CRS technical efficiency can be decomposed into ‘pure’ technical efficiency and scale efficiency. This scale efficiency measure can be roughly interpreted as the ratio of the average product of a firm operating at the point a_{vrs} to the average product of the firm operating at the a point of (technical) optimal scale (point C). This measure of scale efficiency does not indicate whether the firm is operating at an area of increasing or decreasing returns to scale. The nature of scale inefficiencies that is due to increasing or decreasing returns to scale for a particular firm can be determined by seeing whether the non-increasing returns to scale (NIRS) technical efficiency scores is equal to the VRS_{TE} scores. If they are unequal as indicated by point B, increasing returns to scale exists for that firm.

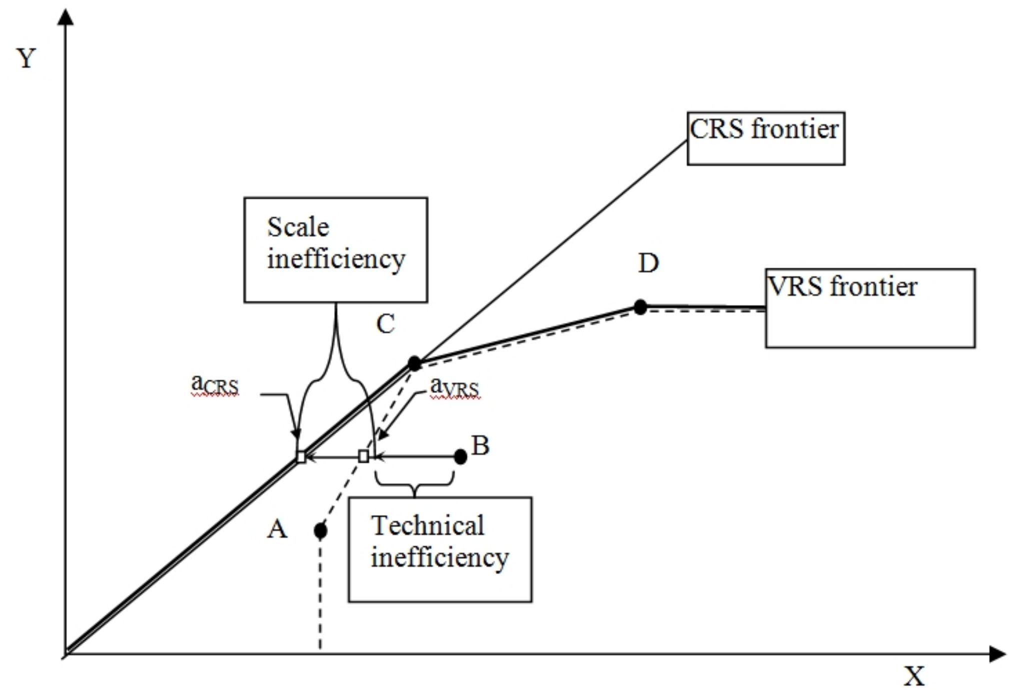

Fig. 1. Input-oriented calculation of scale economies in data envelopment analysis (DEA)

Source: Cooper; Seiford and Tone (2000)

2. MATERIALS AND METHODS

This research work was carried out in Ogo-Oluwa Local Government Area of Oyo State. Ogo-Oluwa local government is lying between latitude 6ºN and longitude 4ºE of Greenwich meridian with annual temperature of 26.2ºC, mean annual rainfall is 1247mm, heavy rain and high humidity period in August and wet between September and October. Eighty respondents were drawn from the list of soybean growers association provided by Apex Farmers Association in Nigeria (AFAN) using simple random sampling. Data for this study was mainly primary data that was collected with the use of structured interview schedule from the respondents. The study made use of descriptive statistics and Data Envelopment Analysis (DEA), a non-parametric frontier was used to estimate the efficiency indexes of soybean farmers in the study area.

2.1Technical Efficiency Model

TE; $(y_j, x_j) = Q_1$ is independent of input prices and computed by solving the following input oriented DEA model under CRS assumption.

$$Min \quad Q_1$$

$$Q_1 . \text{a} \qquad - \quad - \quad - \qquad (1)$$

$$S.t$$

$$x_{ij} \; Q_1 - \sum_{i=1}^{m} x_{ij} \; \text{a}_j \; \geq 0$$

$$\sum_{j=1}^{m} y_j \; \text{a}_j - y_j \geq 0$$

$$for \; \forall_j ; \; Q_1 \; unconstrained$$

If Q = 1 the farm is on the frontier and is technically efficient under CRS.

2.2 Economic Efficiency Model

To derive the overall economic / cost efficiency, we first solve cost minimizing DEA model under the CRS assumption.

$$MC_j \left(y_j, x^*_{ij} \right) \quad = \quad \min_{x^*_{ij}} C_{ij} \; . \; x^*_{ij} \qquad - \quad - \quad - \qquad (2)$$

$$S.+ \quad \sum_{j=1}^{n} y_j \; \text{a}_j - y_j \geq 0$$

$$x^*_{ij} - \sum_{j=1}^{n} y_j \; x_{ij} \; \text{a}_j \geq 0 \geq 0$$

$$\text{a}_j \geq 0 \quad f \quad \forall_j$$

Where MC_j (y_j, x_{ij}, C_{ij}) is the minimum total cost under CRS assumption.

γ_j values are the weights to be used as multipliers for the input levels of the jth farm to indicate the input level that the farm aim at to achieve efficiency. EE is then defined as the ratio of minimum to actual observed costs.

$$E\,E\left(yj\;\;yj,\;xij,\;Gj\right) = \frac{\left[MC\left(y_j;\;x^*_{ij};\;c_{ij}\right)\right]}{\left(c_{ji}\quad x\;x_{ij}\right)} \qquad - \qquad - \qquad - \qquad (3)$$

If $E\,E_j = 1$, then the farm j is considered economically efficient.

2.3 Allocative Efficiency Mode

AE is computed by using Farrell (1957) decomposition relationship.

$$AE;\;\left(y_j,\;x_{ij},\;c_{ij}\right) = \frac{\left[EE_j\;\left(y_j;\;x_{ij},\;ci_j\right)\right]}{\left[TE_j\;\left(y_j;\;x_{ij}\right)\right]} \qquad - \qquad - \qquad - \qquad - \qquad (4)$$

2.4 Determinants of Inefficiency Model

A second step regression model was applied to determine the farm specific attributes in explaining inefficiency in some studies such as Kalirajan (1991). Alternatively, the factors can be incorporated directly into the model. The pros and cons of these approaches are provided in Kumbhakar et al. (1991). This study applied a second step approach by using a Tobit regression.

The model assume

$$y^* = \quad , + \quad {}_1Z_i + \quad {}_2Z_2 + \quad {}_3Z_3 + \quad {}_4Z_4 + e \quad \text{--} \; (5)$$

$$y = \begin{cases} y^* & if\;\; y^* < 100 \\ 100 & otherwise \end{cases}$$

Where y is a DEA efficiency model and used as a dependent variable.

Z_1 = education
Z_2 = farm size
Z_3 = frequency of extension contact
Z_4 = experience

β is the unknown parameter vector associated with the farm specific attributes and e is an independently distributed error term assumed to be normally distributed with zero mean and constant variance, δ^2.

Therefore, the model assumed that there is underlying, stochastic index equal to ($Z\beta$ + e) which is observed only when it is less than 100 and qualified as an unobserved latent variable. The dependent variable, that is efficiency invest cannot be normally distributed but censored distribution because it has a value between 0 and 1. OLS will yield an inconsistent estimate, hence this study used Tobit regression model using maximum likelihood estimate (MLE) approach (Tobin, 1958).

The expected value becomes

$$E(y/z) = 1 - \text{¤}\ (b)\ x\ \ 100 + \text{¤}\ (b)\ Z\ \ \ - \text{¢}\ \text{¤}\ (b)$$

$$where\ b = \frac{(100\ -\ z\ \ )}{\text{¢}} \qquad - \qquad - \qquad - \qquad - \qquad (6)$$

3. RESULTS AND DISCUSSION

3.1 Technical, Allocative and Economic Efficiency of the Farms

The technical allocative and economic efficiencies of soybean farmers are presented in table 1. These efficiencies were aggregated into a frequency distribution with class interval of 0.10. The range of efficiency index varies great with minimum of 0.827, 0.135 and 0.128 and maximum of 1.0 for technical allocative and economic efficiencies respectively. The mean efficiency which indicates the average potential that exists in soybean production in the study area is 0.94, 0.892 and 0.839 for technical, allocative and economic efficiency respectively. Of 80 soybean farmers involved in the analysis only one was found to be technically, allocatively and economically efficient. The measures of relative allocative and technical efficiency provide evidence as to the source of deviations from overall cost-minimizing behaviour. Many sampled soybean farms employed the 'wrong' input mix, given input prices, so that, on average, costs were 11 per cent higher than the cost minimizing level. However, farms have the potential to reduce their physical input, on average, by 6 per cent, and still produce the same level of soybean output. Effort was not made in this study to decompose the TE into pure TE and scale efficiency (SE).

With the number of soybean farmer that are inefficiency suggests the need to strengthen the existing level of resources used to increase their income at the existing level of available resources rather than a technological change. Hence, there exist a potential of 31.25% for technically inefficient farmers to produce at the frontier. Table 1 further showed that with the allocative index of 0.892, thus implied that the soybean farmer in the study area have about 10% potential to efficiently allocate (combine) their resources. It was observed from Table 1 that inefficiency results in large part from allocative inefficiency (10.8%) rather than technical inefficiency (0.06%). This suggests that inefficient soybean farmer use fewer resources to achieve maximum production but do not combine their resources (input) efficiently. This finding is similar to Huynh and Mitsuyasu (2011) which found out that soybean farmers in Vietnam achieve higher TE but poor AE which was attributed to the farmers' decision on the amount of inputs for cultivation was based on their experiences and not using input flexibilities according to the markets.

Table 1. Frequency distribution of efficiency index

	TE	**AE**	**EE**
<0.7	0	1	2
0.70-0.80	0	5	14
0.81-0.90	0	12	41
0.91-0.99	55	21	10
1	25	41	13
Mean	0.940	0.892	0.839

Source: Data analysis, 2010

3.2 Cost Minimizing Input Quantity of Soybean Farms

Summary of mean cost minimizing input quantities showed that on the average, the input used can be reduced to 18.5; 5435.99; 14.15; 1353.08 and 19592.71 for X1; X2; X3; X4 and X5 respectively. This indicates that so many saving could be made if the respondents are cost efficient. Table 2 showed thethe efficiency scores of the descriptive statistics having the lowest dispersion of 0.04 around the mean.

Table 2. Descriptive Statistics of the Efficiency Indices

Efficiency Measure	Mean Score	Standard deviation	Minimum	Maximum
Technical efficiency	0.94	0.04	0.827	1
Allocative efficiency	0.89	0.10	0.135	1
Economic efficiency	0.84	0.10	0.128	1

3.3 Determinants of Efficiency Differentials among Soybean Farmers

The determinant of efficiency differentials among farmers was equally examined for TE, AE and CE using firm-specific factors such as frequency of extension contact, age, experience and education using Tobit regressions explaining efficiency as defined in equation 5 and 6. The Tobit regression coefficients are interpreted to analyze the directional relationship between efficiency and covariates. The results in Table 3 showed that the education parameter has a consistent positive relationship with all the three efficiency indexes but only significant for AE at 1% probability level. This imply that the more educated the farmer is, the more likely efficient he is probably as a result of their better skills and willingness to identify and adopt new innovations. Similar results were reported in Parikh et al*.* (1995) and Battese et al*.* (1996).

Table 3. Tobit Regression Showing Relationship between Selected Farm Specific Factors and Efficiencies Index

variable parameter	TE		AE		EE	
	Coef	t-value	Coef	t	Coef	t
Constant (β_o)	0.92	1.84	0.24	1.714	0.59	4.533
Education (β_1)	0.001	0.125	0.459	8.054***	0.002	0.1
Age (β_2)	0.301	2.168**	0.05	1.05	0.460	3.999***
Extension (β_3)	0.006	0.6	0.01	0.25	0.356	1.967*
Experience (β_4)	0.01	0.2	0.05	0.15	0.03	0.16

** 10% level of significance, ** 5% level of significance and *** 1% level of significance*
β_i Signifies the parameter estimates

The farmer's age has a positive and significant influence on TE and EE efficiency index at 5% and 1% probability levels respectively. This suggests that younger farmers' characteristics are likely to be less efficient than the older ones probably because of experience that might have been acquired over the years. This finding is consistent with findings of Ajibefun et al. (1996) and Seyoum et al. (1998). Extension visit has a positive and statistical influence on the economic efficiency at 10% probability level. This implies that farmers that were visited by extension agents were more likely to be economically efficient than those not visited by extension agents.

3.3 Spearman Rank Correlation Depicting Relationship among TE, AE and EE

The Spearman rank correlations between different measures of efficiency are presented in Table 4. This estimate provides weak but significant estimates between TE and AE with a strong but significant relationship between TE and EE. This finding suggests that a technically efficient farm would not necessarily be allocative efficient.

Table 4. Spearman Rank Correlation of Efficiencies index

	TE	AE	EE
TE	1.00	0.49*	0.89*
AE	0.49*	1.00	0.76*
CE	0.89*	0.77*	1.00

**Signifies significance at 1% probability level*

4. CONCLUSION

The priority of this study is to identify the economic efficiency of soybean production and various drivers through which the soybean farmers' performance can be improved. It was observed that there exists more potential that remained untapped in soybean production in the study area and that the economic inefficiency observed was more as a result of allocative inefficiency rather than the technical inefficiency. The TE and AE was found to be 0.94 and 0.89 respectively, this suggests that an increase in output is possible with a decrease in the cost if the soybean farmers uses the right input mix. Age and frequency of access to extension service were found to significantly impact on both TE and AE. The study therefore suggest based on the findings that the extension teaching should focus more on the appropriate or right combination of input resources given the price as this was found to contribute more to the economic inefficiency than technical inefficiency.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Aigner, D.J., Lovell, C.A.K., Schmidt, P.J. (1977). Formulation and estimation of stochastic frontier production function models. Journal of Econometrics, 6, 21-37.

Ajibefun, A.I., Battese, G.E., Daramola, A.G. (1996). Investigation of factors influencing the technical efficiencies of smallholder croppers in Nigeria. Center for Efficiency and Productivity Analysis (CEPA) Working Paper No. 10/96. Department of econometrics, University of New England, Armidale, Australia.

Ali, M., Chaudhry, M.A. (1990). Interregional farm efficiency in Pakistan-Punjab: Frontier Production Study. Journal of Agricultural Economics, 41, 62-74.

Battese, G.E., Coelli, T.J. (1995). Estimation of frontier production functions and the efficiency of Indian farms using panel data. Journal of Quantitative Economics, 5, 327-348.

Battese, G.E., Malik, S.J., Gill, M.A. (1996). An investigation of technical inefficiencies of production of wheat farmers in four districts of Pakistan. Journal of Agricultural Economics, 47, 37–49.

Charnes, A., Cooper, W.W., Rhodes, E. (1978). Measuring the efficiency of decision-making units. European Journal of Operation Research, 2, 429-444.

Charnes, A., Cooper, W.W., Rhodes, E. (1985). Preface to topics in data envelopment analysis. Annals of Operation Research 2.

Coelli, T.J. (1995). Recent development in frontier modelling and efficiency measurement. Australia Journal of Agricultural Economics, 39, 219-245.

Fare, R., Grosskopf, S., Lovell, C.A.K. (1994). Production Frontier. Cambridge University Press, Cambridge.

Farrell, M.J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society, 120, 252-290.

Food and Agriculture Organization. (1982). Food and Nutrition: A new view of an old problem.

Food Policy and Nutrition Division Nutrition Newsletter, No. 4.Food and Agriculture Organization, Rome.

Greene, W.A. (1990). A Gamma-distributed stochastic frontier model. Journal of Econometrics, 46, 141-164.

Haddad, L., Alderman, H. (2000). Eradicating malnutrition: Income growth or nutrition programmes? The Life Cycle of Malnutrition. International Food Policy Research Institute, New York.

Huynh, V.K., Mitsuyasu, Y. (2011). Productive Efficiency of Soybean Production in the Mekong River Delta of Vietnam, Soybean - Applications and Technology, Prof. Tzi Bun Ng(Ed.), ISBN:978-953-307-207-4, InTech, Available from: http://www.intechopen.com/books/soybean-applications-and-technology/productiveefficiency-of-soybean-production-in-the-mekong-river-delta-ofvietnam.

IART. (1987). Information on Soybean utilization, science technology policy and fund Launching exhibition of Agricultural Research and training, Ibadan Nigeria.

Kalirajan, K. (1991). The importance of efficient use in the adoption of technology: A Micro-panel Data Analysis. Journal of Productivity Analysis, 2, 113-126.

Knipscher, H.C., Peter, A.Y. (1982). The potential of soybean in Nigeria and the result in two Principal Areas (Benue State and Zenkwa Abuja).International Institute of Tropical Agriculture, Ibadan Nigeria Annual Report.

Kumbhakar, S., Ghosh, S., McGuckin, J. (1991). A Generalized Production Frontier Approach for Estimating Determinants of Inefficiency in U.S. Dairy Farms. Journal of Business and Economic Statistics, 9,279-286.

Lassitar, A.I. (1981). Factors affecting the nutrition quality of soybean and soybean products. Journal of American Oil Chemist's Society, 13, 10.

Louisa, C., Sean, P., Simon, M. (1998). DEA vs econometric analysis of efficiency in fisheries. Proceedings of the 9th International Conference of the International Institutes of Fisheries Economics and Trade, Tromsø-Norway.

Mebrhatu, J., Hanna, A. (1986). Soybean Production and Utilization in Africa: An Agro nutritional farming system package strategic planning and study Division, Inter-National Institute of Tropical Agriculture, Ibadan, Nigeria.

Meeusen, W., Van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed Error. International Economic Review, 18(2), 435-444.

Moradeyo, A.O., Arene, C.J. (2010). Constraints and determinants of technical efficiency in medium-scale soybean production in Benue State, Nigeria. African Journal of Agricultural Research, 5(17), 2276-2280.

Olorunsanya, E.O., Babatunde, R.O., Orebiyi, J.S., Omotosho, J.O. (2009). Economic analysis of soybean production in Kwara state, north central Nigeria. Global Approaches to Extension Practice (GAEP), 5(2), 45-53.

Parikh, A., Ali, F., Shah, M.K. (1995.). Measurement of Economic Efficiency in Pakistani Agriculture. American Journal of Agricultural Economics, 77, 675–85.

Seiford, L.M., Thrall, R.M. (1990). Recent Development in DEA: The mathematical programming approach to frontier analysis. Journal of Econometrics, 46, 7-38.

Seyoum, E.T., Battese, G.E., Fleming, E.M. (1998). Technical efficiency and productivity of maize producers in Eastern Ethiopia: A study of farmer within and outside the Sasakawa-Global 2000 Project. Agricultural Economics, 19, 341-348.

Sharma, K.R., Leung, P., Petterson, A., Chen, H. (1999). Economic efficiency and optimum Stocking Densities in Fish Polyculture: An Application of DEA to Chinese fish Farms. Aquaculture, 180, 207-221.

Stevenson, R.E. (1980). Likelihood function for generalised stochastic frontier estimation. Journal of Econometrics, 13, 57-66.

© 2012 Ajao et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=138&id=2&aid=684.