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# Estimation and the determinants of technical efficiency among small scale Soyabean farmers in Nigeria: Evidence from central agricultural zone

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**Abstract:** The study estimated technical efficiency and its determinants among small scale soyabean farmers in the Central Agricultural Zone in Nigeria. Data were collected from 485 soyabean farmers, sampled through a multi-stage procedure, using structured questionnaire. Cobb-Douglas regression functional form, using the stochastic frontier production function, was used to analyze the data that were collected. The estimated technical efficiency ranged from 10% to 99% with a mean of 53%. The study revealed that the important factors having positive impacts on technical efficiency levels were education, farming experience, farm size, extension contact, access to credit and improved soyabean variety, while age and household size had negative influence. The study recommends that policies designed to increase technical efficiency should be directed at increasing access to education and credit, farm size, extension contact and use of improved varieties.
**Keywords**: Small-scale soyabean farmers,technical efficiency,Cobb-Douglas production function, stochastic frontier model

## INTRODUCTION

Over the past two to three decades, the dominant role of agriculture in the Nigerian economy, especially in ensuring food security, gave way to massive importation of basic food items especially grains like rice, beans and millet (CBN, 2007). Agriculture in Nigeria from 1970 to 2000 grew at 1.7 percent per annum relative to the population growth rate of 2.7, with fluctuating agricultural levels leading to annual negative growth in agriculture. Thus, the performance of agriculture has been unsatisfactory with low rates of growth, resulting in pervasive rural poverty and food insecurity in the country, which needs to be addressed urgently.

In an attempt to revitalize the agricultural sector, theFederal Government initiated several policies, agricultural development programmes and projects, aimed at transforming the dominant traditional agriculture through the adoption of modern farm technologies. Modern farm technologies are known to be technically and economically more efficient than the traditional technologies. Due to the importance of soyabean production to the GDP and food security of the country, the government has paid considerable attention to soyabean production by establishing programmes and projects to boostsoyabeanproduction.Amongotherprogrammes are the National Special Programme for Food Security (NSPFS) aimed at increasing agricultural productivity in areas where the country has comparative advantage and expanding the frontiers of rural household options using technologies for arable crop production, and the State Mandate Crop Programme (SMCP), which was adopted as a business development strategy on the basis of its potential in poverty reduction and food security (BNARDA, 2005).

These programmes imply zoning of production, which means that communities direct their efforts towards the production of goods and services which they have a comparative advantage over other communities. The crops considered under theseprogrammes include: Sesame, cocoa, cassava, gum Arabic, maize, oil palm, groundnuts, cotton and soyabean. These crops basically are "cash" crops, and are also referred to as "mandate" crops. States of Central Agricultural Zone of Nigeria, where soyabean is predominantly produced, were mandated via the programmes to produce soyabean among other crops, depending on the available resources and the prevailing ecological potential. Shaib *et al*. (1997) recorded that the Central Agricultural Zone is the largest rice, groundnut and soyabean producer in Nigeria, producing well over 40 percent rice and groundnut as well as 64 percent of soyabean.

Despite these efforts, the performance of agricultural contribution to the nation's GDP has continued to decline,it declined to about 23 percent by mid 1980's (CBN, 1991). However, there was an improvement in the sector's contribution to the nation's GDP in the 2000s as it contributed 41.2 and 42 percent in 2005 and 2006 to the GDP, respectively(CBN 2006).Substantial opportunities exist to raise soyabean productivity in Nigeria by increasing the efficiency with which resources are used at the farm level, especially in soyabean production. This is because many studies have shown that Nigerian soyabean farmers are not fully efficient in resource use (Otitoju and Arene, 2006;Amaza and Ogundari, 2006;Ugela, 2008;Olorunsanya *et al*., 2009;Owor, 2010;).

The broad objective of this study is therefore to estimate the technical efficiency and its determinants among small holder farmers in Central Agricultural Zone in Nigeria, using the stochastic frontier

production function. Technical efficiency refers to the ability to produce the highest level of output with a given bundle of resources (that is, ability to produce on production frontier). Previous studies on technical efficiency of soyabean farmers seem to be restrictive and limited.The study by Otitoju and Arene (2006) was limited to the technical efficiency of Benue State soyabeanfarmers.Also, Ugela (2008) and Owor (2010) used stochastic frontier production to estimate technical efficiency of soyabean production in Benue State;Amaza and Ogundari (2006) and Olorunsanya *et al*. (2009) estimated technical efficiency of Borno and Kwara States soyabean farmers, respectively.This study estimates the technical efficiency of Nigerian soyabean farmers at a wider scope as it covers Central Agricultural Zone which consists of eight States. Results of the study provide useful information for policy makers informulatingprogrammes related to expanding food production of the Zone. The test hypothesis is that soyabean farmers in the Zone were not technically efficient.

## METHODOLOGY

The study area, Central Agricultural Zone in Nigeria, comprises seven States, namely: Benue, Kogi, Niger, Kwara, Nasarawa, Taraba and Plateau as well as the Federal Capital Territory, Abuja. The Zone is the largest soyabean producing Zone in the country (Shaib *et al*., 1997). A multistage sampling technique was used to purposively select Benue, Niger and Plateau States, based on their high level of soyabean production in the Zone.From the list of all soyabean farmersobtained from the respective States' Agricultural Development Projects, which formed the sampling frame, the respondents were randomly drawn to obtain 0.2 percent of each State's soyabean farming population.A total sample of 485 respondents were selected comprising 240, 125 and 120 from Benue, Niger and Plateau States, respectively. Data were obtained through the use of structured questionnaire,administered to the selected 485 respondents, to elicit information on socioeconomic characteristics and production resources

### Theoretical model

Theoretically, a stochastic production function is defined by

$Y_i = f(X_i; B) \exp (V_i - U_i)$, i=1,2,……(1)

Where $Y_i$ is output of the $i^{th}$ farm, $X_i$ is the vector of input quantities used by the $i^{th}$ farm, B is a vector of unknown parameters to be estimated, f represents an appropriate function (e.g. Cobb Douglas, translog, etc.). The term $V_i$ is a symmetric error, which accounts for random variations in output due to factors beyond the control of the farmer such as, weather, disease outbreaks, measurement errors, etc, while the term $U_i$ is a non-negative random variable representing inefficiency in productionrelative to the stochastic frontier. The random error $V_i$ is assumed to be independently and identically distributed as N $(o,\sigma^2_v)$ random variables independent of the $U_i$, which are assumed to be non-negative truncations of the N $(o,\sigma^2_u)$ distribution (i.e. half-normal distribution) or halve exponential distribution.

The stochastic frontier model was independently proposed by Aigner *et al*. (1977) and Mecusen and Van-den Broeck (1977). The technical efficiency of an individual farmer is defined in terms of ratio of the observed output to the corresponding frontier output, given the available technology.

Technical efficiency (TE) = $Y_i/Y_i^*$

$= f(X_i;B) \exp (V_i - U_i)/f(X_i;B)\exp (V_i)$

$= \exp (-U_i)$……..(2)

Where $Y_i$ is the observed output and $Y_i^*$ is the frontier output.

The parameters of the stochastic frontier production function were estimated using the maximum likelihood method.

### Empirical model

The technology of soyabean farmersin Central Agricultural Zone in Nigeria is assumed to be specified by the Cobb-Douglas production frontier function. This function, according to Ogundari and Ojo (2006), has been used by many empirical studies, particularly those relating to developing countries' agriculture. The Cobb-Douglas stochastic frontier production model estimated is defined as:

$LnY_i = \beta o + \beta_1 Lnx_{1i} \beta_2 LnX_{2i} + \beta_3 LnX_{3i} + \beta_4 LnX_{4i} + \beta_5 LnX_{5i} + V_i - U_i$------(3);

where:

$Y_i$ =soyabean output of the $i^{th}$ farmer in kilograms per hectare

$X_{1i}$ = farm size in hectares,

$X_{2i}$ =labour in man-days per hectare,

$X_{3i}$ = quantity of seeds planted in kilograms per hectare,

$X_{4i}$ = the total amount of fertilizer applied in kilograms per hectare,

$X_{5i}$ = agro-chemicals in litres per hectare, and

$\beta o$ - $\beta_5$ =regression parameters to be estimated.

In order to determine factors contributing to the observed technical efficiency, the following model was formulated and estimatedjointly with the stochastic frontier model, using a single stage maximum likelihood estimation procedure,using thecomputer softwareFrontier Version 4.1 (Coelli, 1996).

$TE_i = \sigma_0 + \sigma_1 Z_{1i} + \sigma_2 Z_{2i} + \sigma_3 Z_{3i} + \sigma_4 Z_{4i} + \sigma_5 Z_{5i} + \sigma_6 Z_{6i} + \sigma_7 Z_{7i} + \sigma_8 Z_{8i} + \sigma_9 Z_{9i}$……..(4)

Where:

$TE_I$= technical efficiency of the $i^{th}$ farmer,

$Z_{1i}$ = age of the farmers in years,

$Z_{2i}$ = educational level of farmers in years,

$Z_{3i}$ = farming experience of farmers in years,

$Z_{4i}$= improved soyabeanvariety,

$Z_{5i}$ = number of extension contactsin a year,

$Z_{6i}$= membership of farmers cooperatives (member = 1, non member = 0),

$Z_{7i}$ = access to credit (access = 1, no access - 0),

$Z_{8i}$ = household size in numbers, and

$\sigma_0$- $\sigma_8$ = parameters to be estimated.

$Z_2$, $Z_3$, $Z_4$, $Z_5$, $Z_6$, $Z_7$ and $Z_8$ are expected to have positive influence while $Z_1$ is expected to have a negative influence on technical efficiency.

## RESULTS AND DISCUSSION

### Socioeconomic characteristics of soyabeanfarmers

The frequency distribution of the socioeconomic characteristics of the sampled farmers is presented in Table 1.The result shows that most (44.1%) of the farmers were within the age range of 21-40 years; the mean age was found to be 46 years. The result agrees with the findings of Ogunwale (2000) that the mean age of farmers in Nigeria is between 45 to 48 years; andNwachukwu and Ezeh (2007), that this group forms the cream of productive work force which suggests a high tendency for dynamism and innovativeness. Since the age of farmers has relationship with the quality and quantity of work they can carry out on the farm,the result implies that most of the farmers sampled can effectively carry out farm operations. Furthermore,since the older farmers tend to be more conservative and less vulnerable to the wind of change involving the adoption of modern technologies than younger farmers(Olagunju and Adeyemo,2007), the result implies that farmers in the study area are likely to be receptive to technological innovations.

Analysis of gender shows that soyabean farming is dominated by male farmers(86.7%). This result is in contrast with the findings of Sigot (1995), that womenin Africa are responsible for an estimated 70 percent of total food production throughout the continent. A majority of the sampled farmers(86.8 percent) were married. The high proportion of married respondents suggests that family labour could be available for soyabean farming in the study area, and the farmers likely to be stable in their places of farming as marriage is associated with occupational stability. Marriage, according to Igben(1980), is one of the most important factors influencing production and productivity. The study reveals an average household size of 9 members with 1-10 members accounting for 64.7 percent. The high average household size suggests high availability of family labour for soyabean farming operations in the study area. A large household size is an obvious advantage in terms of farm labour supply. This is in agreement with Ekong (1988) and Sule (2006) that large household size characterizes a typical traditional African society with large blood relations, who have a great role to play in family labour in the agricultural sector.

Majority (69.9 percent) of respondents had some level of formal education;40 percent attended secondary school, 15.9 percent had primary education while 14 percent attained tertiary education. This finding contradicts the reported high illiterate status of farmers from Central Agricultural Zone of Nigeria(Shaib *et al*.,1997), but agrees with Ochepo (2010) who found a high percentage (92.8%) of rural people who are mostly farmers to be educated at various levels in the Zone. The high proportion of literates among the sampled farmers suggests that farmers in the study area are likely to be receptive to new improved, technology which could have positive implications on their productivity.

A majority of (63.7%) of respondents had farm sizes between 1-2 hectares with only 1.2 percent having upward of farm hectares, giving an average of 1.57 hectares. This indicates that farmers in the study area were predominantly small-scale operators based on the classification of farm holdings in Nigeria by Olayide(1980), that small scale holds 1-5.99 hectares, medium scale 6-9.99 hectares and large scale upward of 10 hectares.

Credit availability is critical to agricultural operations in Nigeria.The results of our study show that majority(71.8%) had no credit access, which agrees with the separate findings of Otubusin (1986) and Lawal (2000) that access to credit is a major constraint to farmers in Nigeria. Since access to credit provides farmers with means of expanding and improving their farms (Tijani *et al*.,2006), limited credit access could reduce their efficiency by limiting their ability to procure farm inputs and information needed for improved productivity.

Table 1: Distribution of respondents according to their socioeconomic characteristics

| Variables | Frequency | Percentage |
|---|---|---|
| Age (years) | | |
| ≤ 20 | 65 | 13.4 |
| 21 - 40 | 214 | 44.1 |
| 41 – 60 | 179 | 36.9 |
| ≥ 60 | 27 | 05.6 |
| Mean = 46.0 | | |
| **Sex** | | |
| Male | 420 | 86.6 |
| Female | 65 | 13.4 |
| **Marital Status** | | |
| Single | 27 | 05.5 |
| Married | 421 | 86.6 |
| Widowed | 25 | 5.2 |
| Divorced | 12 | 02.5 |
| **Household Size** | | |
| 1-10 | 314 | 64.7 |
| 11-20 | 115 | 23.7 |
| 21-30 | 46 | 9.5 |
| ≥ 30 | 10 | 2.1 |
| Mean = 9.19 | | |
| **Educational Status** | | |
| No Formal edu. (0yrs) | 146 | 30.1 |
| Prim. Sch. (6yrs) | 77 | 15.19 |
| Sec. edu (12yrs) | 194 | 40.0 |
| Tertiary Edu (16yrs) | 68 | 14.0 |
| Mean = 12years | | - |
| **Farming exp (years)** | | |
| ≤ 15 | 160 | 33.0 |
| 16 – 30 | 268 | 55.3 |
| 31 – 45 | 57 | 10.5 |
| ≥ 45 | 06 | 1.2 |
| Mean = 20.77 | | |
| **Farm Size (ha)** | | |
| 0.1 – 2.0 | 309 | 63.7 |
| 2.1 – 3.0 | 117 | 24.1 |
| 3.1 – 4.0 | 42 | 08.7 |
| 4.1 – 5.0 | 11 | 0.23 |
| ≥ 5.0 | 06 | 01.2 |
| Mean = 1.57 | | |
| **Access to Credit** | | |
| Access | 137 | 71.8 |
| No Access | 348 | 28.2 |

Source: Field Survey, 2010

**Production function estimates**

The maximum likelihood estimate of the stochastic frontier model for soyabean production is presented in Table 2. The sigma squared ($\sigma^2$=0·23) is significant at 1 percent level of probability, indicating a good fit and correctness of the distributional assumption specified. The gamma (γ) estimate of 0.99 is statistically significant at 1 percent. This implies that the one-sided random inefficiency component strongly dominates the measurement error and other random disturbances, indicating that about 99 percent of variation in actual output from maximum (production frontier output) between farms arose mainly from differences in farmers' practices and management rather than random variabilities (technical inefficiency). These factors are under the control of the farmer and the influence of which can be minimized to enhance technical efficiency. The coefficients of farm size (0.22), labour(0.31), seed(0.16) and fertilizer(0.09) are positive and

statistically significant at 1 percent while that of agrochemicals is positive but not significant. This implies that a 1 percent increase in farm size,labour, seed and fertilizer would lead to 2.2,3.1,1.6 and 0.9 percent increase, in output of soyabean, respectively.

Table 2: Maximum likelihood estimates of the parameters in the stochastic frontier model of soyabean farmers in Central Agricultural Zone in Nigeria.

| Variables | Parameters | Co-efficient | t-values |
|---|---|---|---|
| Constant | $\beta_0$ | 6.76 | 37.57*** |
| Ln Farm size | $\beta_1$ | 0.22 | 5.69*** |
| Ln Labour | $\beta_2$ | 0.31 | 6.57*** |
| Ln seed | $\beta$ | 0.16 | 4.27*** |
| Ln fertiliser | $\beta_4$ | 0.09 | 3.79*** |
| Ln agrochemicals | $\beta_5$ | 0.04 | 0.36 |
| Sigma squared | $(\sigma^2)$ | 0.23 | 14.85*** |
| Gamma | $(\gamma)$ | 0.99 | 66.17*** |
| Log likelihood function | | -334.09 | |
| LR test | | 223.85 | |

Source: Field Survey, 2010.
***t- values significant at 1 percent

The frequency distribution of the technical efficiency indices of soyabean farmers is presented in Table 3. The individual technical efficiency estimates of the farmers range between 0.10 to 0.99 with a mean of 0.53. Furthermore, 55.3 percent had a technical efficiency index between 0.31 and 0.60 while 5.8 percent were in the range of 0.91 to 1.00. The average soyabean farmer in the sample would save 46(1-0.53/0.99) percent while the most technically inefficient could realize a cost saving of 90(1-0.10/0.99) percent if he/she attains the technical efficiency level of the best practiced soyabean farmer among the respondents. These results indicate that majority of farmersin Central Agricultural Zone in Nigeria achieved moderate technically efficient production. The mean technical efficiency of 53 percent obtained for soyabean in the study area is lower than the mean of 98 percent obtained for soyabean in the Guinea Savannas of Nigeria from Borno State by Amaza and Ogundari (2006) but compares favourably with the mean of 55 percent obtained by Ugela (2008) in his study of resource use efficiency in soyabean production in Benue State. The level of technical efficiency obtained in this study suggests that opportunities exist for increasing productivity and income through increased efficiency by 47 percent, which is the average inefficiency level of sample farmers, by adopting the technologies and techniques used by the best practiced soyabean farmers.

Table 3: Distribution of technical efficiency estimates of soyabean farming in Central Agricultural Zone in Nigeria.

| Efficiency range | Frequency | Percent |
|---|---|---|
| <0.30 | 58 | 12.0 |
| 0.31-0.60 | 268 | 55.3 |
| 0.61-0.90 | 131 | 27.0 |
| 0.91-1.00 | 28 | 5.8 |
| Total | 485 | 100 |
| Mean | 0.53 | |
| Minimum | 0.10 | |
| Maximum | 0.99 | |

Source: Field Survey, 2010

**Determinants of technical efficiency**

The determinants of technical efficiency in soyabean production (see Table 4)in Central Agricultural Zone of Nigeriawere education, farm size, farming experience, extension contact, improved variety, membership of farmers cooperatives and access to credit, and positively and significantly related to technical efficiency, while age and household size are significant but negatively related to technical efficiency. The result implies that except for age and household size, these factors increase the technical efficiency of soyabean farmers.

The positive relationship between improved soyabean variety and technical efficiency is likely due to the fact that when improved varieties are planted they yield more than traditional/local

varieties. The positive significant role of improved variety agrees with Tchale *et al*.(2008) that farmers that grow hybrid maize are about 5 percent more efficient than those that grow local maize varieties. The positive relationship between credit and technical efficiency is consistent with those of Onyenweaku and Ohajianya (2005), and Onyenweaku *et al*.(2005) in their efficiency studies of rice and yam production in South Eastern and Northern Nigeria, respectively; Bravo-Ureta and Evenson (1994) in their study of peasant farmers production efficiency in Eastern Paraquay and Linguard *et al*.(1983) in a comparative efficiency of rice farmers Philippines. The result, however, differs from that of Okike (2000) who found a negative relationship between credit and technical efficiency in estimating economic efficiency of crop / livestock interaction of farmers in Northern Nigeria.

The positive and significant relationship between education and technical efficiency agrees withOnu *et al*.(2000) in their findings on economic efficiency of cotton production in Nigeria; Belbase and Grabowski(1985) in technical efficiency in Nepalese agriculture; Kalarijan and Shand (1986) in estimating location-specific technical efficiency of Malaysian agriculture; and Bravo-Ureta and Pinheiro (1995) who measured technical, allocative and economic efficiencies in Dominica.The positive influence of farming experience is consistent with those of Onyenweaku and Ohajianya (2005), and Onyenweaku *et al*.(2005)Kalirajan (1981), and Kalarijan and Flinn (1983) in their efficiency studies of yield variability in paddy production in India and farm specific technical efficiency in Philippines, respectively.

The positive influence of membership of farmers associations/cooperatives is consistent with the result of Okike (2000) in Northern Nigeria. Members of farmers associations have more access to agricultural information, credit and other production inputs as well as more enhanced ability to adopt innovations. The positive influence of extension contact is in accordance with a priori expectation that extension contact leads to more efficient transmission of information to farmer as well as enhancing the adoption of innovations and agrees with those of Onyenweaku and Ohajianya (2005), Onyenweaku *et al*. (2005), Kalirajan (1981), Kalirajan and Flinn (1983).

The negative and significant relationship of age is in consonance with a prori expectation that as the farmers advance in age they become less efficient in production. Ageing farmers would be less energetic to do strenuous work, thus leading to low productivity as well as low technical efficiency. This is in line with the findings of Okoye, *et al*. (2007).The negative significant influence of household size is likely due to the fact that larger household provide higher family labour which may not be efficient in carrying out farm operation due to lack of efficient supervision because of family bond.

Table 4: Estimated determinants of technical efficiency in soyabean production in central Agricultural Zone, Nigeria

| Variables | Parameters | Co-efficients | t-values |
|---|---|---|---|
| Constant | $\sigma_0$ | 6.90 | 6.67*** |
| Age | $\sigma_1$ | -1.00 | 2.51** |
| Education | $\sigma_2$ | 0.22 | 2.38** |
| Farm experience | $\sigma_3$ | 0.56 | 14.86*** |
| Extension contact | $\sigma_4$ | 0.23 | 4.16*** |
| Improved variety | $\sigma_5$ | 0.06 | 2.11** |
| Membership of farmers' cooperative | $\sigma_6$ | 0.19 | 2.49** |
| Access to credit | $\sigma_7$ | 0.06 | 2.37** |
| Household size | $\sigma_8$ | -0.09 | -2.25** |

Source: Field Survey, 2010.
***and** t-values significant at 1 and 5 percent, respectively.

## CONCLUSION AND RECOMMENDATIONS

The individual technical efficiency indices of soyabean farmers in Central Agricultural Zone of Nigeria range from 10 to 99 percent with a mean of 53 percent. This result suggests that there are ample opportunitiesto increase productivity and income of soyabean farmers in the study area, by increasing the efficiency with which resources are used at the farm level. The mean technical index of 53 percent implies that there is scope for increasing production of soyabean by 47 percent, by adopting the best practiced technologies and techniques.

Factors that had significant positive influence on technical efficiency of the soyabean farmers were education, farm size, extension contact, improved soyabean variety, membership of farmers' cooperatives and access to credit. Policies aimed at increasing soyabean farmers' technical efficiency should encompass improving farmers' access to credit, education and improved soyabean varieties, through the establishment of sustainable microcredit

schemes and greater investments in formal education as well as technology development and transfer. Also, farmers should be encouraged to increase farm sizes through provision of adequate tractor hiring services, and strengthening of farmers cooperatives by providing improved inputs to farmers timely and adequately through farmers cooperatives. Experienced farmers should be encouraged to remain in soyabean farming and extension services more proactive and effective.

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