Identification and Stochastic Analysis of Factors Influencing Technical Inefficiency of Nigerian Smallholder Soybean Farmers

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Summary

Smallholder soybean production is investigated using an econometric analysis otherwise known as stochastic frontier analysis through transcendental logarithmic (translog) production function, which incorporates an inefficiency effects model. Ninety-six farmers were randomly selected through multistage techniques in Benue State, Nigeria. Factors (socio-economic and institutional) considered in the inefficiency effects model include household size, sex, age, years of schooling, farming experience in soybean production, health status, off-farm employment, non-family labour, credit accessibility, land fragmentation and extension contact. The parameters of the stochastic frontier translog production function are estimated contemporaneously with those involved in the inefficiency effects model. The results indicate that household size, age, non-family labour were significant and negatively related to the technical inefficiency while farming experience, off-farm employment, credit accessibility, land fragmentation, and extension contact were statistically significant and positively related to the inefficiency. The mean technical efficiency of the farmers is 0.84. This means that the farmers can still improve their efficiency level by 16%.

Résumé

Identification et analyse stochastique de l'inefficacité technologique des petits producteurs du soja au Nigeria

La production du soja chez les petits agriculteurs au Nigeria est étudiée par une analyse économétrique de la frontière stochastique. Le modèle de l'inefficacité est utilisé pour apprécier la fonction de production logarithmique transcendantale (translog). Quatre-vingt-seize producteurs ont été choisis, aléatoirement, en utilisant une technique d'échantillonnage stratifié dans l'État de Benue. Les facteurs socio-économique et institutionnel (la taille du ménage, le sexe, l'âge, le niveau de formation, l'expérience dans la production du soja, l'état de santé, l'emploi hors-exploitation agricole, la main-d'œuvre non-familiale, l'accès au crédit, le morcellement des terres, et le nombre de contacts avec les conseillers techniques) ont été étudiés. Les paramètres de la frontière stochastique translog sont comparés avec ceux impliqués dans le modèle d'effets d'inefficacité. Les résultats indiquent que la taille du ménage, l'âge, la main-d'œuvre non-familiale étaient statistiquement significatifs et négativement corrélés à l'inefficacité technique. Par contre, l'expérience dans la production du soja, l'emploi hors-exploitation, l'accès au crédit, le morcellement des terres et l'ampleur des contacts avec les vulgarisateurs étaient statistiquement significatifs mais positivement corrélés à l'inefficacité. L'efficacité technique moyenne des producteurs est de 0,84. Ce qui signifie que ceux-ci peuvent encore améliorer leur niveau d'efficacité de 16%.

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Introduction

Nigeria is the largest producer of soybean for food in the West and Central Africa (28), and more recently, Nigeria was ranked the largest producer of soybean in Africa in the year 2003 by the International Development Research Centre (IDRC), Canada (15). Almost all the tonnage of soybean in the sixties was produced in Benue State (25), solely produced on small scale farms of less than 6.0 hectares in size. Recently the presidential initiative on Vegetable Oil Development Programme (VODEP) launched in 2002, which was to address five oil-producing crops- cocoa, oil palm, cotton, groundnut and soybean, in order to meet the 300,000- 400,000 tonnes per annum supply deficit of vegetable oil (26). Interested institutions like the International Institute of Tropical Agriculture (IITA) and Institute of Agricultural Research (IAR), ABU, tried in the generation of improved, adaptable (TGX and TGM) and Samsoy varieties, respectively, to replace the Malayan variety first introduced to the country (6).

Due to the improved protein level of soybean and low price, there have been increasing demands for soybean in Nigeria, both for domestic consumption and industrial use. Oyebanji (24) reported that soybean production in 2004 increased by 9.9% over that of 2003. Despite this increase there is still widened demand-supply gap. To bridge this gap even at this present technology level, there is need to examine factors explaining why domestic soybean supply lags behind the demand for the commodity in Nigeria. Central to this is the issue of efficiency of Nigerian soybean farmers in the use of available resources or technology. Ajibefun *et al.* (3) opined that efficiency of production is central to raising production and productivity of African agriculture. Although several studies have been carried out on estimation of efficiency in Nigerian agriculture e.g. (2, 3, 5, 20, 21), none of these studies looked into the issue of determining the factors influencing technical efficiency of soybean-farmers. The only study that attempted to determine the cause of technical inefficiency among soybean-farmers is that of Kondoun (17). The major drawback in that study is that the author restricted technical efficiency differentials to educational attainment.

Technical efficiency measurement may be generally divided into two groups according to method chosen to estimate the frontier production function, namely mathematical programming versus econometric estimation (10). The mathematical programming approach to frontier estimation is usually termed Data Envelopment Approach (DEA). DEA is a deterministic model and all deviations from the production frontier are attributed to inefficiencies (10, 23). This assumption of DEA, is difficult to accept, given the inherent variability of agricultural production, due to weather, fires, pests, diseases, etc. Also, many farms smallholders, keeping of accurate records is not always a priority (10). Thus DEA is very sensitive or likely to be subject to measurement errors (10, 23).

In agricultural economics literature, use of SFA has generally been preferred; this is probably associated with the inherent variability or uncertainty of agricultural production (10, 11, 23). There have been many applications of frontier production functions in literature in developing agricultural economies. For example, many studies attempt to investigate the relationship between technical efficiencies and various socio-economic (3, 7, 20, 22, etc.). Most of the applications which seek to provide explanation to differentials in technical efficiencies in agricultural production use a two-stage approach e.g. (5, 16, 21). This paper used one-stage stochastic frontier production function that incorporates the technical inefficiency model to identify factors that influence technical inefficiency among Nigerian smallholder soybean farmers not to violate maximum likelihood assumption of error independence in two interrelated models.

Materials and methods

This study was conducted in Benue State, Nigeria. The choice of Benue state was because it is ranked the largest producer of soybean in Nigeria. Following 2006/07 cropping season, 96 smallholder soybean farmers were selected through purposive and multi-stage sampling techniques. Four Local Government Areas (Ushongo, Ukum, Gboko and Tarka) were purposively selected and 96 respondents were randomly selected with the help of the extension workers of Benue State Agricultural and Rural Development Authority (BNARDA) at the zone, block and cell levels. Data was gathered through personal interview using a set of pre-tested questionnaire or interview schedule.

Empirical model: The Stochastic frontier and inefficiency models

The data was fitted into Cobb-Douglass and transcendental logarithmic functional forms (Equations I and II).

(i). Cobb-Douglass production form (Equation I):

$$ln\, y_1 = \beta_o + \sum \beta_i \ln(x_i) + (v_i - u_i) \qquad \text{I}$$

(ii). The stochastic transcendental logarithmic (translog) frontier production form (Equation II):

$$ln\, y_1 = \beta o + \sum_{i=1}^{3} \beta i\, lnxi + \frac{1}{2} \sum_{i \leq j=1}^{3} \sum^{3} \beta ij \ln Xi \ln Xj + Vi - Ui \qquad \text{II}$$

Where: Σ represents the natural logarithm; stands for summation; j= represents the input variables in the second-order term of the translog model; y_i= output of soybean harvested for the ith farmer (in kilogramme); X_i= i[th] input variables in the model; X_1= total labour used in man-days; X_2= total area of land planted to soybean in hectares; X_3= total fertilizer used in soybean production in kilogrammes. β_o is the constant parameter. β_i is the parameter estimate of the ith variable. The V_{is} are random errors that are assumed to be independent and identically distributed as N (o, σ_v^2) random variables; and the U_{is} are non-negative technical inefficiency effects that are assumed to be independently distributed among themselves and between V_{is} such that U_i is defined by the truncation i or a half-normal of the N distribution. The inefficiency Model (Equation III):

$$\mu_I = \delta_o + \sum \delta_j Z_{ji} \qquad \text{III}$$

Where: U_i is the technical inefficiency of the i[th] farmer; δ_s unknown scalar parameters estimated; δ_o is the parameter estimate of the constant in the inefficiency model; δ_j is the parameter estimate of the determinant jth in the inefficiency model. The following variables were hypothesized as factors that influence technical inefficiency; Z_1= Farmer's household size (number of persons in the household); Z_2= Sex of household head (1 for male; 0 otherwise); Z_3= Age of household head (in years); Z_4= Years of schooling of household head; Z_5= Farming experience in soybean production (in years); Z_6= Health status (1 for presence of sick member (s) of the household i.e. protracted sickness and 0 otherwise); Z_7= Off-farm employment (1 for off-farm employment and 0 otherwise); Z_8= Non-family labour in man-days; Z_9= Credit accessibility (1 for access to credit and 0 otherwise); Z_{10}= Land fragmentation (Number of fragmented land used in soybean production in the cropping season); Z_{11}= Extension contacts (Number of visits in the cropping season).

Results and discussion

Table 1 presents summary of the variables of interest in the efficiency analysis. The farms involved are relatively small with average size of 2.19 hectares. The average age of the respondents was 33. 31 years, this shows that the respondents were relatively young people. The average output of soybean for the cropping year was 1741.11 kilogrammes. The average year of schooling of the farmers was 11.31 years, meaning majority barely complete primary school. It is assumed here that more years of schooling is expected to have an inverse relationship with technical inefficiency (i.e. reduce the technical inefficiency). Many of the farmers did not receive extension services during the cropping year as evidenced by the average of 0.28. This low extension contact or visits is at

Table 1
Summary statistics of variables used in the efficiency analysis.

Variable	Mean	Standard Deviation	Minimum	Maximum
Output (Kg)	1741.11	1081.99	300	5550
Household size (Number)	6.44	4.41	1	32
Age of farmers (Years)	33.31	9.38	20	65
Years of schooling (Years)	11.31	3.51	0	16
Farming experience (years)	8.70	6.45	0	16
Farm size(hectare)	2.19	1.20	0.5	5.5
Fertilizer (kilogramme)	134.22	168.75	0	750
Extension contact (Number of visits)	0.28	0.45	0	1
Land fragmentation	3.69	2.12	1	10

variance with the expectation of more visits of the extension personnel to provide technical support to Nigerian smallholder soybean farmers. The mean value of farming experience in soybean production was 8.70 years. It is assumed in some studies as the proxy for human capital. Most adoption studies have attempted to measure human capital through the farmer's age and their education or years of experience growing the crop (12, 13). If this is true, the recorded average years of farming experience (8.70 years) might not have a significant effect on reducing the technical inefficiency of the farmers as expected. The capital resource considered in the analysis is fertilizer with an average of 134.22 kg. There is a problem of farm holdings with an average of fragmented land of 3.69.

Stochastic Frontier Production Function Estimates: An Econometric Approach

The maximum likelihood estimates (MLE) of the parameters of the stochastic frontier model were obtained using the computer programme FRONTIER 4.1 which provides estimates of β, σ_u^2, $\sigma_v^2 = \sigma_s^2$ and $\Upsilon = \sigma^2/\sigma_s^2$ as well as individual and average farm-level efficiencies.

There was presence of efficiency effects using the generalized likelihood ratio when tested.

Test of the null hypotheses was obtained by using the generalized likelihood-ratio statistic, which is defined by equation IV:

Where L (H_o) is the value of the likelihood function

$$\lambda = \frac{-2ln[L(H_o)]}{ln L(H_1)} = -2ln[L(H_o) - L(H_1)] \quad \text{IV}$$

for the frontier model, in which the parameter restrictions specified by the null hypothesis, H_0 are imposed; and L (H_1) is the value of the likelihood function for the general frontier model. If the null hypothesis is true, then λ has approximately a Chi-square (or a mixed square) distributed with degrees of freedom equal to the difference between the parameters under H_1 and H_0, respectively; that is the number of parameters excluded in the model.

The results of testing the two null hypotheses of interest (as seen in Table 2) show that the first hypothesis H_0: $\beta_{ij}=0$, $i \leq j = 1, 2, 3$, which specifies that the Cobb-Douglas frontier model is an adequate representation of the data, is strongly rejected for small scale soybean production, hence, the data from Nigerian smallholder soybean farms are better analysed with the translog frontier model. The second null hypothesis, H_o: $\gamma = \delta_o = \delta_1 \ldots = \delta_{11} = 0$, which states that inefficiency effects are absent from the frontier model, is rejected, indicating that there were presence of technical inefficiency effects in Nigeria smallholder soybean production. The discussion of the results of this study is strictly based on the transcendental logarithmic stochastic frontier production function (the preferred model).

Maximum likelihood estimates (MLE) for parameters of the two estimated models are presented in table 3. The relative importance of the inputs is shown by their signs and magnitude as shown in the production function. Only land is according to the *a priori* expectations, that is, it was positively signed and statistically significant at 1% level, which indicates a direct relationship with the output. This implies that a unit increase in farm size will increase the output of soybean by about 87 percent. Labour is highly significant at 1% level but inversely related with output of soybean, meaning that a unit increase in labour will decrease soybean output by about 62 percent. This may be due to small farm size holding per individual which led to under utilization of labour. It may be due to overutilization of family labour by farm household heads in soybean production. The estimated value for the Υ- parameter is quite large and significant (0.89) and significant, which means that the inefficiency effects are highly significant in the analysis of the value of output of the farmers.

The estimated coefficients in the explanatory variables (socio-economic and institutional) in the model for the inefficiency effects are of interest and have important policy implications as in table 4. Factors that have negative sign and are at the

Table 2
Generalised log likelihood-ratio tests of null hypotheses.

Null hypothesis	Log-likelihood	Test statistics	Critical value*	Decision
H_0: bij =0, i≤j = 1, 2, 3.	-19.66	48.69	12.59	Reject H_0
H_0: g = 0	4.689	72.64	21.00	Reject H_0

Table 3
Maximum Likelihood Estimates (MLE) of Frontier Production Function for Nigerian Smallholder Soybean Farmers.

Variable	Parameter	Cobb-Douglas Coefficient	t-ratio	Translog[a] Coefficient	t-ratio
Constant	β_0	5.197 -1.054	4.929*	24.923 -1.530	16.288*
Ln(labour)	β_1	0.296 (0.195)	1.519*	-6.155 (0.622)	-9.899*
Ln(land)	β_2	0.755 (0.181)	4.170*	0.874 (0.149)	5.878*
Ln(Fertilizer)	β_3	0.016 (0.012)	1.271**	0.420 (0.429)	0.979
0.5[Ln (labour)]^2	β_{11}	0	-	0.510 (0.069)	7.385*
0.5[ln(land)]^2	β_{22}	0	-	-0.741 (0.119)	-6.221*
0.5[ln(fertilizer)]^2	β_{33}	0	-	0.006 (0.012)	0.510
[ln(labour)]x[ln(land)]^2	β_{12}	0	-	0.202 (0.034)	5.912*
[ln(laour)x[ln(fertilizer)]^2	β_{13}	0	-	-0.079 (0.082)	-0.961
[ln(land)x[ln(fertilizer)]^2	β_{23}	0	-	-0.053 (-0.072)	0.730
Variance Parameters					
Total Variance	δ_s^2	0.861 (0.400)	2.152*	0.262 (0.0760	3.475*
Gamma	Y	0.961 (0.091)	51.323*	0.889 (0.059)	15.024*
Log-likelihood function	LLF	-19.656		4.689	

Values in parenthesis are standard error

a preferred model; * significant at 5% i.e. a preferred model ; * significant at 5%; ** significant at 10%.

Note: After the log-likelihood ratio test the discussion of the Maximum likelihood estimation was based on the preferred model i.e. transcendental logarithmic model.

Table 4
Factors influencing technical inefficiency of Nigerian smallholder soybean farmers.

Variable	Parameters	Coefficient	Standard error	t-ratio
Constant	δ_0	-0.678	0.0950	-0.714
Household size (Z_1)	δ_1	0.214	0.0426	-5.030***
Sex (Z_2)	δ_2	-0.0498	0.377	-0.132
Age (Z_3)	δ_3	-0.488	0.0261	-1.833*
Years of schooling (Z_4)	δ_4	0.0278	0.0554	0.502
Farming experience (Z_5)	δ_5	0.0418	0.0268	1.556
Health status (Z_6)	δ_6	-0.124	0.303	-0.409
Off-farm employment (Z_7)	δ_7	0.643	0.470	1.369
Non-family labour (Z_8)	δ_8	-0.00225	0.00154	-1.461
Credit accessibility (Z_9)	δ_9	0.787	0.245	3.214***
Land fragmentation(Z_{10})	δ_{10}	0.267	0.00956	2.780***
Extension contact (Z_{11})	δ_{11}	0.962	0.342	2.814***

Source: Computed from field data, 2007

*** significant at 1% level

* significant at 10% level

same time significant (household size and age) shows that they have decreasing effect on the technical inefficiency, while those with positive signs and are significant (credit accessibility and land fragmentation) have increasing effect on technical inefficiency.

The negative coefficient for the household size (*Z_1*) is significant at 5%, implies that soybean farm households with more members are less technically inefficient, than those with few members (household size reduces technical inefficiency). This may be so because large household sizes may not guarantee increased efficiency since family labour, which comprises mostly children of school age, are always in school and are not available for farming activities in most cases. Where such large household members are available for farming activities, farm size is small for all members to work effectively and hence there is under utilization of labour, which makes the law of diminishing marginal returns to set in. This result agrees with the finding of Birungi and Hassan (9) which found out that household size is negatively related to adoption of fallow as land management technology in Uganda.

The negative coefficient for the age (*Z_3*) and significant at 5% implies that the younger soybean farmers are more technically efficient than the older soybean farmers. It is assumed that the younger the farmer, the more likely he/she is to adopt innovations early in his/her respective life cycle (27). Older farmers may have a shorter time horizon and be less likely to invest in novel technologies and at the same time they may not even have the experience needed to combine the inputs as expected for greater results. Studies supported that younger farmers adopt novel technologies and are venturesome than their older counterparts, among them are the work of Alexander and Mellor (4) which found that GM corn adoption increased with age for younger farmers as they gain experience and increase their stock of human capital but declines with age for those farmers closer to retirement. Similar result was discovered by Bayard *et al.* (8) that the age of farmers has a negative influence on adoption of rock walls as soil management practice in Fort-Jacques in Haiti and on adoption of rbST in Connecticut Dairy Farms (14). On the contrary, this finding is a deviation from the findings of Ajibefun *et al.* (3) and Ojo (22) in which they found out that technical inefficiency tends to increase with age (i.e. technical efficiency decreases with age).

The positive coefficient for credit accessibility variable (Z_9) but significantly at 5% shows that the more access to credit the more technically inefficient the farmers. This is contrary to a priori expectations that farmers' access to credit should reduce their level of technical inefficiency. This indicates that farmers who have access to credit tend to exhibit higher levels of inefficiency. It might be as a result of credit received being misused (or diverted to other uses). It could probably be that there is fungibility of credit gotten which could have resulted in moral hazard which is a problem due to information asymmetry. There is need for supervised credit.

Land fragmentation variable (Z_{10}) has positive coefficient but significant at 5%, which shows that the more the number of fragmented land put to soybean production the more technically inefficient the farmers. This might be that it takes more time for farmers to move from one plot to others which definitely have effect on increasing the farmer level of technical inefficiency in soybean production in Benue State, Nigeria. Invariably, the less the number of land fragments the more technically efficient the farmers would be. This implies that there is need to enhance and effectively put to use land use decree that will be farmers friendly to enable them have access to a versed land size for their soybean farming activities.

There is also a positive coefficient for the extension contact variable (Z_{11}) but significant at 5%, this shows that as extension contact increases the more inefficient the farmer could be but this is at variance with essence of extension services provision especially the public extension type. This finding agrees with the findings of Ajibefun *et al.* (2) of mixed Croppers, which found that an increase in extension contact would decrease the level of technical efficiency (or increase the level of technical inefficiency). But the finding here disagrees with the findings of Ajibefun *et al.* (2) of cassava croppers, rice croppers and maize croppers. This could probably be that the methods of disseminating newly introduced technology were not good enough for the farmers to understand. Better and simpler farmers participatory and demand driven methods should be used with emphasis on the importance of farmer-farmer paradigm in technology transfer.

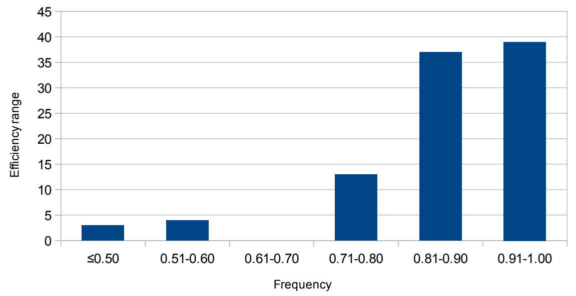

Figure 1: Frequency distribution of efficiency level of Nigerian smallholder soybean farmers.

Technical Efficiencies Estimates for Nigerian Smallholder Soybean Farmers

The technical efficiency level shows the ability of farmers to derive maximum output from the inputs used in soybean production. A very important characteristic of the stochastic production frontier model is its ability to estimate individual, farm-specific technical efficiencies. Given the preferred model (transcendental logarithmic) the estimates of the technical efficiency is as presented below. Figure 1 shows high variability among Nigerian smallholder soybean farmers, the computed technical efficiency varies between 0.102 and 0.96 with mean of 0.84 (84%). This result is similar to the result of Kurkalova and Jesen (19) which found that the average technical efficiency of grain-producing farms in Ukraine was 0.82 (82%) in 1989 cropping year. The highest number of farmers (40.62%) has technical efficiencies between 0.91 and 1.00 follow by 38.54% of the farmers having technical efficiencies between 0.81 and 0.90. The sample soybean farmers' frequency distribution indicates a clustering of technical efficiencies in the region 0.81- 1.00 efficiency range, indicating that the farmers are fairly efficient. There appears to be considerable room for the farmers to improve their efficiency level by 16% using the present technology.

Conclusion

The findings of this study reveal that household size, age, credit accessibility, land fragmentation and extension contact influenced the technical inefficiency level of Nigerian smallholder soybean farmers. The farmers still have advantage of reducing their technical inefficiencies by 16% with the use of the present soybean technology. Access to credit is positively related to small-scale soybean farmers' technical inefficiency, credit should be made available and accessible to the farmers, so that they would be able to procure necessary productive resources, fertilizer, to increase or expand their soybean production. Nigerian Agricultural Cooperatives and Rural Development Bank (NACRDB), the Central Bank of Nigeria (CBN) through its agency, the Agricultural Credit Guarantee Scheme Fund (ACGSF), the microfinance institutions, and other government institutions saddled with similar responsibilities should be mandated to give thorough supervision and monitoring to ensure timely release of credit to the soybean farmers. Soybean farmers (especially small-scale farmers) should be provided with adequate extension services and training programmes on entrepreneurship skills needed in understanding and using present soybean technologies to enhance their efficiency. This type of training can be provided by institutions like the Cooperative Extension Centre (CEC) of the University of Agriculture, Makurdi, College of Agriculture, Yandev, Benue state, Nigeria Soybean Association (NSA) and other critical actors in soybean production.

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