African Journal of Agricultural Research Vol. 5(21), pp. 2909-2917, 4 November, 2010
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X ©2010 Academic Journals

Full Length Research Paper

Technical efficiency of traditional and hybrid maize farmers in Nigeria: Comparison of alternative approaches

Goodness C. Aye* and Eric D. Mungatana

Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, South Africa.

Accepted 31 August, 2010

In this study, technical efficiency of traditional and improved maize farms as well as impact of technological innovation on technical efficiency were investigated. Two-stage procedure was followed. In the first stage, technical efficiency scores were obtained from four different models namely parametric stochastic distance frontier, parametric stochastic production frontier and two non-parametric distance frontiers and the results were compared. In the second stage, efficiency estimates from each of the four methods were regressed against hybrid seed and other policy variables using Tobit model. A total of 240 farm households were selected for the study using a multistage random sampling technique. The selected households were interviewed using semi-structured questionnaires. Results showed that farmers operated with substantial technical inefficiency irrespective of the approach employed. Technical efficiency estimates obtained from the distance frontier approaches are positively and significantly correlated. In all the models, hybrid seed was found to have positive and significant impact technical efficiency. Other policy variables that had significant impact on technical efficiency include education, extension, credit and land. These results reinforce the need for further investment in agricultural research and development for increased productivity, food security and poverty reduction in Nigeria.

Key words: Technical efficiency, technology, maize, alternative approaches, Nigeria.

INTRODUCTION

The global food crisis is increasing with alarming speed and force, necessitating nations and international organizations all over the globe to respond with a strategic and long term approaches aimed at curbing the food crisis. The current crisis is caused by a web of interconnected forces involving agriculture, energy, climate change, trade, and new market demands from emerging markets (CSIS, 2008). These have grave implications for economic growth and development, international security, and social progress in developing countries. Although, Nigeria heavily depends on oil revenue, the role of agriculture on economic growth in Nigeria cannot be overemphasized. It contributes about 42% to the national GDP and this value is the highest among all the other sectors (Central Bank of Nigeria, 2007). About 64.4 and 83.7% of the population lives below the $1.25 and $2 a day, respectively (UNDP, 2009). Over 70% of the poor live in rural areas and majority depends on agriculture for livelihood. Smallholder farmers in Nigeria produce about 90% of Nigeria's total food production and about 60% of the country's population depends on these small farms for livelihood (Oluwatayo et al., 2008).

Maize, one of the major staples in Nigeria, is one of the vital concerns to agricultural policy decisions. Current maize production is about 8 million tonnes and its average yield is 1.5 tonnes per hectare. The average yield is lower compared to the world average of 4.3 tonnes/ha and to that from other African countries such as South Africa with 2.5 tonnes/ha (FAO, 2009). There has been a growing gap between the demand for maize and its supply. The stronger force of demand for maize relative to supply is evidenced in frequent rise in price of maize and therefore, has great implication for the food security status and economic development of the

---

*Corresponding author: E-mail: aye_goody@yahoo.co.uk. Tel: +27 74 405 7623.

Nigerian economy. It is reported that among other causes of the food crisis, gross underinvestment in agricultural production and technology in the developing world with donors and developing countries has contributed to static productivity, weak markets, and underdeveloped rural infrastructure (CSIS, 2008). To stem the tide of the current food problem, the Federal government in 2006 initiated a programme of doubling maize production in Nigeria through promotion of improved production technologies such as fertilizer, hybrid seeds, pesticides, herbicides and better management practices. Since then, several stakeholders have alleged their support for this program. Several improved maize varieties, drought-tolerant, low nitrogen-tolerant, Striga-tolerant, stemborer-resistant and early maturing, have been deployed to address the challenge faced by resource-poor farmers in maize production. Despite these efforts, maize productivity remained low thus raising question about the efficiency with which resources are used by both hybrid and traditional farmers. More importantly, for a justification of further investment in agricultural production and technology development in general and maize in particular, there is a need to assess the feasibility of investment made so far.

It is against this background that this study is to analyze the technical, allocative and cost efficiency of smallholder maize production and to evaluate the impact of hybrid technology on these efficiency measures. Different approaches exist for efficiency analysis and different approaches may produce different results leading to various policy conclusions. However, if different approaches give similar results, it implies that the measures of efficiency and the explanations of relative efficiency with respect to the variables of interest (for instance technological innovation and other policy and policy related variables as in this study) can be used as basis for policy recommendations. Two competing broad approaches are usually used in efficiency analysis, namely parametric and non-parametric approaches. The parametric approach makes assumption about the form of production technology and distribution of the error terms (the appropriateness of which raises some questions), the later does not. Generally, the non-parametric approach does not account for possible noise in the data and statistical inference cannot be drawn from its results. However, the non-parametric approach has advantage of not imposing any functional form on the production technology.

The present study is to investigate the sensitivity of efficiency results to alternative approaches. Majority of comparative studies compare SFPF and DEA (Ferrier and Lovell, 1990; Kalaitzandonakes and Dunn, 1995; Sharma et al., 1999; Wadud and White, 2000; Ajibefun, 2008). In recent years, analysis involving distance functions as an alternative representation of the production technology has begun and only few studies has compared results from parametric distance functions to other approaches (Coelli and Perelman, 1999; 2000; Arega and Manfred, 2005; Arega et al., 2006). None of these studies especially those related to Agriculture accounted for the possible stochastic noise in the data in a distance function framework. The aim of the current study is to fill these knowledge gaps by comparing two parametric stochastic approaches namely stochastic input distance function (SIDF) and stochastic frontier production function (SFPF) and one non-parametric approach namely data envelopment analysis (DEA). This paper deals with parametric stochastic frontiers against the alternative of parametric deterministic frontiers given agriculture's susceptibility to variability and production shocks.

MATERIALS

In the absence of a reliable household census data, a field survey was conducted by using a pre-tested semi-structured questionnaire. This survey was carried out in Benue State Nigeria during the 2008/2009 agricultural season. The state is the nations well known acclaimed food basket, a name given it for producing the bulk of Nigeria's food and it is located in the North Central Zone. A multistage stratified sampling procedure was employed in selecting the respondents in this study. The first stage involved a purposeful selection of two zones among a total of three agricultural zones in the State based on their adequate representation of distinct maize production. The second stage involves two Local Government Areas selected randomly from each zone. The third stage involves a random selection of 60 maize farm households from the selected local government areas. Fourth stage involves selection of the household head. Thus, a total of 240 farmers were interviewed.

Data on output and input quantities and prices were collected. One output variable (PROD) and four input variables (LAND, LABOUR, FERT and OTHER) were used to estimate the parametric stochastic input distance function. The output variable is the quantity of maize produced during 2008/2009 agricultural season by a farm household and is measured as kg. LAND is measured as the area of land in hectares cultivated with maize by a farm household in the relevant period. LABOUR is measured as the amount of both family and hired labour in man days used by the farm household. FERT is the amount of inorganic fertilizer in kilograms used by the farm household. OTHER is the Fisher quantity index of seed, herbicides and pesticides used by the farm household (Coelli et al., 2005).

A number of variables were used to provide evidence of the magnitude and direction of the impact of technological innovation and other policy variables on efficiency. One variable indexing technological innovation is HYV (area of maize farm cultivated with hybrid seed variety. Other variables include AGE (age of the household head in years), GENDER (dummy variable equal 1 if male or zero otherwise), EDU (number of years of formal education completed by the household head), HHS (number of persons in the household), OFFWORK (dummy variable equal to 1 for engagement in off-farm work), MFG (a dummy variable equal 1 if the household head is a member of any farmer organization), EXT (number of extension visits during the cropping period), CREDIT (a dummy variable equal 1 if farmer had access to credit) and MARKET (distance to the nearest output or input market). The data was also collected on the instruments for HYV namely YIELD which is equal 1 if a farmer perceives that HYV produces more than the traditional variety and 0 otherwise. PALATABILITY is 1 if farmer perceive that HYV is more palatable than the local maize variety and 0 otherwise.

Model specification

For the current study, the empirical models employed are also specified.

Parametric stochastic input distance function (SIDF)

It is assumed in the current study that the Cobb-Douglas (CD) parametric stochastic input distance functions. The specification is admittedly restrictive with respect to the maintained properties of the underlying production technology. However, in order to test the inappropriateness of the CD form, a likelihood ratio test was applied for the available data. The test revealed that the CD input distance function is indeed an adequate representation of the data for maize farmers in Benue State given the specification of the more flexible Translog (TL) form. Additionally, no statistical difference between the efficiency scores attributed to the TL and the CD form was found. Therefore, CD was preferred according to the results of these tests and given TL's susceptibility to multicollinearity (Coelli, 1995; Seymoun et al., 1998; Hassine-Belghith, 2009). In most empirical studies, the selection of orientation is justified based on exogeneity/endogeniety argument for inputs and outputs. However, (Coelli, 1995; Coelli and Perelman, 1999) observed that in many instances, the choice of orientation will have only minor influences upon the efficiency scores obtained. Based on this, the study employs the input orientation and therefore the discussion is limited to input distance function. For the case of single output, K inputs, N farms, the model is specified as:

$$\ln D_i = \delta + \alpha \ln Y_i + \sum_{j=1}^{4} \beta_j \ln X_{ji,} i = 1....N \qquad (1)$$

Where, Y_i is the observed maize output for the i-th farmer and X_{ji} = is the j-th input quantity for the i-th farmer which includes land, labour, fertilizer and aggregation of other inputs. It represents a natural logarithm, and δ , α and β_j are unknown parameters to be estimated. Imposing the restriction for homogeneity of degree +1 in inputs upon Equation (1),

$$\sum_{j=1}^{4} \beta_j = 1, \qquad (2)$$

Thus, the estimating equation can be rewritten as follows:

$$-\ln X_{ki} = \delta + \alpha \ln Y_i + \sum_{j=1}^{4-1} \beta_j \ln\left(X_{ji} / X_{ki}\right) - \ln D_i, \qquad (3)$$

The unobservable distance term "$-\ln \mathrm{D}_{\mathrm{i}}$" represents a random term and can be interpreted as the traditional stochastic frontier analysis disturbance term, ε_i. Thus Equation (3) can be rewritten as follows:

$$-\ln X_{ki} = \delta + \alpha \ln Y_i + \sum_{j=1}^{4-1} \beta_j \ln\left(X_{ji} / X_{ki}\right) + \varepsilon_i, \qquad (4)$$

Where,

$$\varepsilon_i = v_i - u_i \qquad (6)$$

That is, the distances in a distance function could be due to either statistical noise (v_i) or technical inefficiency (u_i), which is the standard SFA error structure. vi are assumed to be ii d $N(0, \sigma_v{}^2)$ and independent of u_i, where u_i is independently distributed. A number of assumptions can be made on the distribution of u_i namely, half-normal, truncated normal, exponential and gamma distributions. The choice of a particular distribution may be tested using the Likelihood ratio test. For this study a likelihood ratio test was conducted between the half-normal and truncated normal distribution, the hypothesis of half-normal distribution could not be rejected at 5% level of significance. Thus, u_i is assumed to have a half-normal distribution $\left|N(0, \sigma_v{}^2)\right|$. Given the distributional assumptions, the values of the unknown parameters can then be estimated by the maximum likelihood method. Following, Betsey and Coelli (1995), the input-orientated technical efficiency (TE) scores can then be predicted using the conditional expectation predictor:

$$TE_i = E[\exp(-u_i) | \varepsilon_i)], \qquad (7)$$

Parametric stochastic frontier production function (SFPF)

The empirical model is specified as:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{4} \beta_j \ln X_{ji,} + v_i - u_i \qquad (9)$$

Where, the variables are similar to those in the SIDF model.

Non-parametric, data envelopment approach (DEA)

Both variable returns to scale (VRS) and constant returns to scale (CRS) DEA models are utilized in this study. The VRS model permits the construction of production frontier to have increasing, constant or decreasing returns to scale. The DEA model could have either an input-orientation or an output-orientation just like its parametric counterpart. However, for appropriate comparison with the parametric approach in the previous section, the discussion is focused on the input-orientated DEA model.

The DEA input-oriented CRS and VRS models are used to obtain the technical efficiency score. The DEA model for the present study is developed for the case of a single output and multiple inputs. Assuming that there are N farms which produce a single output using M different inputs and the i-th farm produces y_i units of output applying x_{ki} units of kth input, the M × N input matrix, X , and the 1 × N output matrix, Y , represent the data for all N farms in the sample. The input-oriented CRS DEA model is specified as:

$$\min_{\theta,\lambda} \theta,$$

$$\text{st} \quad \begin{aligned} & -y_i + Y\lambda \geq 0, \\ & \theta x_{ki} - X\lambda \geq 0, \\ & \lambda \geq 0, \end{aligned} \qquad (8)$$

Where, θ is the input technical efficiency measure having a value $0 \leq \theta \leq 1$. The resultant efficiency measure depicts the distance of each farm unit from the frontier. If the score is equal to one, it implies that the farmer is on the frontier. The vector λ is an N × 1 vector of weights which defines the linear combination of the peers of the i-th farmer. $X\lambda$ and $Y\lambda$ are efficient projections on the frontier. $N1'$ is an N × 1 vector of ones. The linear programming problem will be solved N times, providing a value for each farmer in the sample. The CRS linear programming problem can easily be modified to account for variable returns to scale by adding the convexity constraint: $N1'\lambda = 1$ to Equation (11) in order to provide an input-oriented VRS model. The output variable, y and input variables, x are defined for the SIDF.

Determinants of technical efficiency of maize farmers

In order to examine the role of relevant technological and farm-specific factors on productive efficiency, a second stage procedure is used whereby the efficiency scores are regressed on the selected explanatory variables using a two-limit Tobit model since efficiency scores are bounded between 0 and 1. The Tobit model is specified as:

$$Y_i^* = \beta_0 + \sum_{\substack{j=1 \\ =0}}^{10} \beta_j X_{ij} + \beta_m T_i + u_i \quad \text{if}$$

$$\left. L_i < \beta_0 + \sum_{\substack{j=1 \\ =0}}^{10} \beta_j X_{ij} + \beta_m T_i + u_i < U_i \right\} \qquad (10)$$

Where, Y_i^* is a latent variable representing the efficiency measure (technical, or allocative or cost efficiency) for each farm household, X_i is a $kx1$ vector of explanatory variable for the *i*th farm, T_i is the hybrid maize seed for the *i*th farm viewed as a potential endogenous variables, β_i and β_m is a $kx1$ and $mx1$ vectors of unknown parameters to be estimated, u_i are residuals that are independently and normally distributed, with mean zero and a constant variance σ^2, and L_i and U_i are the distribution's lower and upper censoring points, respectively. Denoting Y_i as the observed dependent variable, $Y_i = 0$ if $Y_i^* \leq 0;$ $Y_i = Y_i^*$ if $0 < Y_i^* < 1;$ and $Y_i = 1$ if $Y_i^* \geq 1$. The inclusion of technology adoption variable in an efficiency model presents the problem of potential endogeneity and self selectivity. The exogeneity of this variable was tested by using the instrumental variable approach as proposed by Smith and Blundell (1986). In order to correct for endogeneity where the exogeneity test is rejected, the study follows a two step approach, in which the endogenous technology variable is estimated in a first stage and their predicted values are included in a second step as additional explanatory variables, which produces unbiased estimates of impact of technological innovation on technical efficiency.

RESULTS AND DISCUSSION

Maximum likelihood estimates of SIDF and SFPF models

The maximum likelihood estimates (MLE) of the parametric stochastic input distance function (SIDF) and parametric stochastic frontier production function (SFPF) are shown in Table 1. In order to qualify as a well-behaved model, SIDF needs to be non-decreasing in inputs and decreasing in outputs (Fare et al., 1994). Result shows that all variables are significant at 5% level and have expected signs and therefore satisfies the required conditions for concavity and monotonicity. The partial output elasticity corresponds to the negative of its estimated coefficient (Coelli and Perelman, 1999). The estimated coefficient of output is less than one (0.74) in absolute terms. For the parametric stochastic input distance function, value less than one implies increasing returns to scale which is computed as the inverse of the negative of the output coefficient (that is, 1/-0.74 = 1.351). This is an evidence to show that the farmers are operating below the frontier and therefore, there is still room for improvement in maize production. Another intuitive interpretation of the elasticity of the distance function for a specific output is that it corresponds to the negative of the cost elasticity of that particular output. The elasticity of maize output being negative and highly significant implies that increasing production of maize results in a substantial increase in cost. The cost elasticity of 0.74 for output, therefore, implies that a 10% increase in maize output results in a 7.4% increase in total cost.

The elasticities of the distance function for input quantities are equal to the cost shares and therefore reflect the relative importance of the inputs in the production process. Table 1 reveals that all the four elasticities are positive, as expected, with reasonable levels of statistical significance. The elasticity with respect to land is largest with a value of 0.67 which means that the cost of that input represents 67% of total cost at the sample mean. This is a very good indicator of importance of land as a factor of production. This result is agreement with their findings of land being a major expenditure component of the surveyed farmers. Labour comes next in terms of cost share with a value of 0.23, suggesting the high opportunity cost and productivity of smallholder labour in Nigeria. The estimated coefficient of 'other' is computed with the homogeneity restriction, and is estimated as 0.06 and seed accounts for a lion share of this contribution. Fertilizer has an elasticity of 0.04. The low elasticity of fertilizer may be as a result of low

Table 1. The MLE estimates of the parametric distance and production frontiers.

Variable	Mean	Parameter	SIDF estimates	SFPF estimates
Intercept		δ	3.883**(0.216)	5.908**(0.145)
Prod	1320.38	α	-0.740**(0.021)	-
Land	1.208	β_1	0.667**(0.024)	0.838**(0.027)
Lab	111.195	β_2	0.233**(0.023)	0.192**(0.029)
Fert	115.185	β_3	0.038**(0.003)	0.050**(0.004)
Other	56.343	β_4	0.061[a]	0.056***(0.010)
Sigma-squared		$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.043**(0.006)	0.067**(0.009)
Gamma		$\gamma = \sigma_u^2 / \sigma^2$	0.825**(0.060)	0.837**(0.051)
LLF			132.274	81.100
RTS			1.352	1.136

**Significant at 5% level. Standard errors are shown in parenthesis; [a] The estimate of β_4 in the SIDF model is computed using the homogeneity condition.

application rates. A similar result was obtained from the SFPF model. Just like the SIDF, maize farmers operate under increasing returns to scale which in the case of SFPF is given by the summation of the coefficients of the input variables. The estimates of the variance parameter, γ is 0.83 and 0.84 in the SIDF and SFPF models, respectively, and are significant at 1% implying that in the SIDF and SFPF models, 83 and 84%, respectively, of the total variation in output is due to inefficiency. This result is confirmed by conducting a likelihood ratio test to test the hypothesis of OLS model versus frontier model. The Log-likelihood function (LLF) for the OLS estimates of the SIDF and SFPF are 125.48 and 72.04, respectively thus providing LR test statistic of 13.23 and 18.11, respectively. These results were significant compared with mixed chi-square value of 5.412 at one degree of freedom, thus rejecting the adequacy of the OLS estimation for the available data. Variance inflation factor (VIF) was used to detect the presence of multicollinearity in each of the models. The mean VIF are 1.21, 4.70, 1.21 and 1.21 for SFPF, SIDF, VRS DEA and CRS DEA models, respectively. These values are less than 10 implying that multicollinearity is not a problem in any of the models.

Comparison of efficiency scores and distribution

The results of the efficiency scores and distribution from parametric SIDF, SFPF and non-parametric DEA models for farmers to use improved and traditional maize varieties are presented in Table 2. For the hybrid seed variety users, technical efficiency (TE) ranges from 65.0 - 97.1 with a mean of 88.7% in the SIDF model. The result implies that the average hybrid variety user lost 11.3 percent of its output for not operating on the frontier. In other words, there is still potential to improve technical efficiency of hybrid seed users by 11.3% through appropriate policies. The result further implies that in the SIDF model, if the average hybrid maize seed user in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer could realize a 8.7 percent cost savings (that is, 1 - [88.7/97.1]). A similar calculation for the most technically inefficiency hybrid maize farmer reveals cost saving of 33.1% (that is, 1 - [65.0/97.1]). For the local seed variety users, technical efficiency (TE) varies from 64.3 to 95.8 with a mean of 79.4% in the SIDF model. The result implies that, the average local variety user lost 21.6% of its output for not operating on the frontier. In other words, there is still potential to improve technical efficiency of hybrid seed users by 21.6% through appropriate policies. The result further implies that in the SIDF model, if the average local maize seed user in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer could realize a value of 17.1% cost savings (that is, 1 - [79.4/95.8]). A similar calculation for the most technically inefficiency local maize farmer reveals cost saving of 32.9% (that is, 1 - [64.3/95.8]). For the rest models, the results are interpreted in the same way. The distribution shows that majority of the farmers fall into the above 80% technical efficiency category in each model. An independent t-test of average technical efficiency of hybrid and local maize seed users was conducted. The result is shown in the last column of Table 2. For each of the models, the test was clearly rejected, implying that hybrid maize farmers are more technically efficient than the local variety users. From the foregoing, it is obvious

Table 2. Frequency distribution, summary and hypothesis of TE measures.

	SFPF	SIDF	DEA VRS	DEA CRS
	Hybrid farmers			
≤ 50	1	0	0	11
51 - 60	1	0	2	2
61 - 70	26	3	11	30
71 - 80	42	13	50	45
81 - 90	58	103	45	40
91 - 100	62	71	82	62
Mean	0.885	0.887	0.874	0.822
Minimum	0.433	0.650	0.556	0.483
Maximum	0.997	0.971	1.000	1.000
Standard deviation	0.091	0.058	0.111	0.144
	Traditional farmers			
≤ 50	0	0	0	10
51 - 60	1	0	9	5
61 - 70	1	11	11	12
71 - 80	9	17	8	4
81 - 90	15	16	6	9
91 - 100	24	6	16	10
Mean	0.844	0.794	0.782	0.721
Minimum	0.581	0.643	0.515	0.375
Maximum	.994	0.958	1.000	1.000
Standard deviation	.109	0.092	0.166	0.182
t-ratio[d]	2.381	8.816	4.643	4.179

[d] implies independent t-test between hybrid and traditional maize farmers.

that maize farmers in Benue State operate with considerable technical inefficiency. Thus, this naturally leads us to seek for sources of technical inefficiency. However, before proceeding to sources of inefficiency, we evaluate the efficiency scores from the different approaches to ascertain the consistency of their results.

The statistical significance of the difference between the parametric SIDF, SFPF and nonparametric DEA efficiency scores was evaluated. This is achieved by testing different complementary hypotheses relative to: i) the equality of means (paired t-test), ii) the equality of distributions (Wilcoxon signed rank-test), and iii) the independence of the results with regard to their rank (Spearman's correlation test). Table 3 presents the results concluding that in the case of the t-tests, the differences between the distance parametric (SIDF and SFPF) and the non-parametric (DEA) technical efficiency scores are statistically significant with a confidence of 95% except for that between SFPF and DEA VRS model. The Wilcoxon test further reinforces this result by indicating that the distributions within the bilateral pairs of results are also statistically different. Similar conclusion could not be made for Wilcoxin test between SFPF and DEA VRS. The Spearman correlation between the SFPF and DEA VRS is very poor though it is statistically significant. Similarly, the correlation between SFPF and SIDF and between SFPF and DEA CRS is negative, very low and statistically insignificant. However, the Spearman's correlation between the parametric and two non-parametric distance function efficiency scores are positive and highly significant. The implication of these findings to model builders is that given the consistency of results from parametric and non-parametric distance function approaches, an integrated approach may be considered appropriate for policy analysis.

Comparison of determinants of efficiency in SFPF, SIDF and DEA models

A major goal of this section is to evaluate the impact of technological innovation on farm efficiency. For direction and magnitude of impact of technological innovation on efficiency, an endogeneity-corrected Tobit model is employed in the second step regression. Summary results for the Smith and Blundell (1986) test of exogeneity is shown in the lower panel of Table 4. The exogeniety of hybrid maize seed adoption was rejected in all the models, thus as a correction, the predicted value of HYV was used in the second stage Tobit analysis. The results of the second stage endogeneity-corrected Tobit model are shown in the upper panel of Table 4. The significance of the likelihood ratio (LR) test for each model implies that the joint significance of all variables included in the model. Thus, the hypothesis that the technology and other policy variables included in the model have no significant impact on efficiency is rejected.

The effect of AGE on technical efficiency could be positive or negative. Older farmers are more experienced and would be more technically efficient than younger farmers. However, older farmers are less likely to adopt new technologies and hence would be less technically efficient than younger farmers. In this study, AGE has a positive sign in all the models and significant impact on TE was found in all models except in the SFPF model. Thus, the variable indexes experience and serve as a proxy for human capital showing that farmers with greater farming experience will have better management skills and thus higher efficiency than younger farmers. Increased farming experience may lead to better assessment of the importance and complexity of good farming decision, including efficient use of farming inputs. This result is in line with the findings of Khai et al. (2008). The second human capital variable, EDU was consistently positive and significant in all the models. Similar positive and significant impact of education on technical efficiency of maize farmers in Nigeria was reported by Oyewo and Fabiyi (2008). HHS was found to be positively and significantly related to technical efficiency in all models except in the DEA VRS. This

Table 3. Hypothesis tests for TE scores from alternative frontiers.

Test	t-test[a] t-statistic	Wilcoxon[b] Z-statistic	Spearman[c] Spearman's ρ
SIDF vs DEA VRS	2.133 (0.034)	2.936 (0.003)	0.705 (0.000)
SIDF vs DEA CRS	8.606 (0.000)	7.900 (0.000)	0.654 (0.000)
SFPF vs DEA VRS	-0.152 (0.871)	0.158 (0.874)	0.025 (0.005)
SFPF vs DEA CRS	4.125 (0.000)	3.997 (0.000)	-0.040 (0.537)
SIDF vs SFPF	1.623 (0.106)	1.164 (0.245)	-0.020 (0.755)

NB: p-values in parenthesis; [a] H0 is the equality of means; [b] H0 is that both distributions are the same, [c] H0 is that both variables are independent.

Table 4. Endogeneity-corrected tobit model results of determinants of technical efficiency.

VARIABLE	SFPF	SIDF	DEA VRS	DEA CRS	MEAN
	Coefficient	Coefficient	Coefficient	Coefficient	
GENDER	-0.009(0.020)	-0.012(0.009)	-0.025(0.030)	-0.034(0.034)	0.888
AGE	0.001(0.001)	0.002***(0.000)	0.004***(0.001)	0.005***(0.001)	47.167
EDU	0.002**(0.001)	0.002***(0.000)	0.005***(0.001)	0.005***(0.002)	8.433
HHS	0.002**(0.001)	0.002***(0.000)	0.001 (0.001)	0.003**(0.001)	11.742
LAND	-0.070*** (0.017)	-0.027***(0.008)	-0.048* (0.027)	-0.142***(0.031)	1.208
OFFWORK	-0.001(0.014)	-0.008 (0.006)	-0.032 (0.021)	-0.020 (0.023)	0.675
MFG	0.012 (0.022)	0.049***(0.011)	0.070**(0.034)	0.119***(0.038)	0.454
EXT	0.007*(0.004)	0.003*(0.002)	0.001 (0.006)	0.006 (0.006)	2.546
CREDIT	0.045**(0.018)	-0.030***(0.009)	-0.046 (0.029)	0.014 (0.032)	0.138
MARKET	-0.003***(0.001)	-0.000(0.000)	-0.004**(0.002)	0.004**(0.002)	6.278
HYV	0.013***(0.002)	0.015**(0.006)	0.037*(0.020)	0.037*(0.022)	0.895
INTERCEPT	0.781***(0.043)	0.732***(0.020)	0.583***(0.066)	0.372(0.075)	0.816
LLF	220.621	400.008	32.659	94.860	0.591
LR TEST	60.880***	258.940	92.640***	26.591	1.750
EXOGENEITY TEST	-0.083***(0.025)	0.023**(0.012)	0.160***(0.041)	0.236***(0.049)	

***Significant at 1% level; **significant at 5% level; *significant at 10% level. Standard errors are shown in parenthesis.

indicates the importance of abundant labour supply which is important for increased productivity.

The variable LAND is aimed at capturing the effect of scale production on the technical efficiency of the farm. A review by Lundvall and Battese (2000) establish a varied relationship between farm size and technical inefficiency in developing countries using the frontier production function. In this study, the sign of the land variable was negative-significant in all the models. This can be explained by the fact that increased farm size diminishes the timeliness of input use leading to decline in technical efficiency. The inverse relationship confirms the findings of Msuya (2008), Okoye et al. (2006, 2009) and Peterson (1997). This finding underscores the need to make policies that favour small scale farmers as they are the backbone of agricultural growth in developing countries. The variable OFFWORK is included to capture the effect of off-farm work on efficiency. The effect of this variable could be ambiguous. While on the one hand, it increases the income base of the farm household thus helping them to overcome credit and insurance constraints and increase their use of industrial inputs. On the other hand, it reduces the labour available for agricultural production especially if hiring agricultural labour incurs transaction costs and if hired labour is not as efficient as family labour (Feng, 2008). In the current study, OFFWORK was consistently negative but not significant. This implies that, farmers in off-farm work are likely to be less efficient in farming as they share their time between farming and other income-generating activities. Productivity suffers when any part of production is neglected. This finding is in agreement with that of Mariano et al. (2010). Membership in a farmer group (MFG) indexes social capital. MFG affords the farmers opportunity of sharing information on modern maize practices and provides them with bargaining power in the input, output and credit markets. As expected, MFG was consistently positive and significant in all the models except the SFPF model.

This is similar with the findings of Ogunyinka and Ajibefun (2004). The GENDER variable was consistently negative though not significant in any of the models.

The extension variable, EXT, presents a little puzzle. It is expected to be positive as it enhances farmers' access to information and improved technological packages. It was however found to be negative and significant in the SFPF model, positive and significant in the SIDF model, negative and positive though not significant in the two non-parametric approaches. Some researchers (Okoye et al., 2006, Ogunyinka and Ajibefun, 2004) in Nigeria have found similar negative sign of the extension variable for technical efficiency. Similar results were in agreement with findings of Haji (2006) for smallholder farmers in Ethiopia. Extension services in Nigeria have generally not been effective, especially after the withdrawal of World Bank funding from the Agricultural Development project (ADP). This calls for the need for more effective policy support for extension services. Additional efforts need to be devoted to upgrade the skills and knowledge of the extension agents as well as ensuring timely dissemination of modern technological inputs and practices. CREDIT is positive and consistently significant in all the models. This is as expected since the availability of credit loses the production constraints thus facilitating timely purchase of inputs and therefore increasing productivity via efficiency. The result is consistent with the findings of Muhammad (2009) but contrast with that of Haji (2006) who rather found a negative impact of credit access on technical, allocative and cost efficiency. The variable MARKET was included to capture farmers' access to market. It serves as a proxy for the development of road and market infrastructures. It is generally believed that, farms located farther from to the market are less technically, allocatively and economically efficient than the farms located closer to the market as this might not only increase production cost but also affect farming operations, especially the timing of input application. In this study the MARKET variable was correctly signed and significant in all models except in the SIDF model.

Finally, an important goal of this study is to evaluate explicitly the impact of technological innovation on efficiency of maize farmers. Results show that HYV has positive and significant impact on technical efficiency in all the models. Chirwa (2007) employed a production frontier model and found a positive and significant impact of hybrid seed use on technical efficiency of smallholder maize farmers in Malawi. These findings further strengthen the need for hybrid seed improvement and diffusion in Nigeria in agreement with the current doubling of maize production programme of the Federal Government. The positive and significant impact of the included technological innovation variable shows the role of government technology policy in enhancing farm efficiency in Nigeria and therefore underscores the need for further investment into agricultural research and technology development.

Conclusion and policy implications

The study demonstrates the application of a range of approaches to analysis of efficiency of traditional and hybrid maize seed users in Benue State Nigeria. The findings show substantial technical inefficiency in maize production in Benue State, Nigeria irrespective of the methodology employed. Further, the study assessed the impact of technology and other policy factors on technical, allocative, and cost efficiency of small scale maize farmers in Nigeria. This was achieved by analysing the technical efficiency of traditional versus improved maize producers. Subsequently, the magnitude and direction of impact was provided in a second stage regression analysis using an endogeniety corrected Tobit model. Results show that the technological innovation variable, hybrid seed, had positive and significant impact on technical efficiency irrespective of the approach employed. It was also found that education, extension contact, age, membership in farmer organization, access to credit, access to market and household size have significant impact on technical efficiency. The infrastructural development of rural areas which makes access to market easy is recommended as this would enhance forward linkage with agro-processing industries which will indirectly increase the price volatility in maize production and thus increase the socioeconomic status of these farmers. These findings stresses the need for appropriate policy formulation and implementation to enable farmers reduce their technical inefficiency in production as this is expected to have multiplier effects ranging from maize productivity growth, food security, food self-sufficiency, increased household income to economic growth and poverty reduction.

REFERENCES

Ajibefun IA (2008). An evaluation of parametric and non-parametric methods of technical efficiency measurement: application to small scale food crop production in Nigeria. J. Agric. Social Sci., 4(3): 95–100.

Arega DA, Manfred Z (2005). Technology adoption and farmer efficiency in multiple crops production in eastern Ethiopia: A comparison of parametric and non-parametric distance functions. Agric. Econ. Rev., 6(1): 5-19.

Arega DA , Manyong VM, Gockowski J (2006). The production efficiency of intercropping annual and perennial crops in southern Ethiopia: A comparison of distance functions and production frontiers. Agric. Syst., 91: 51–70.

Battese GE, Coelli TJ (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empir. Econ., 20, 325-332.

Central Bank of Nigeria (2007). Statistical Bulletin, 18: December.

Centre for Strategic and International Studies (2008). A call for a strategic U.S. approach to the global food crisis: A report of the CSIS task force on the global food crisis, core findings and recommendations.http://csis.org/files/media/csis/pubs/080728_food_ security. pdf accessed 20.09.2009.

Chirwa EW (2007). Sources of technical efficiency among smallholder maize farmers in southern Malawi. AERC Res. Paper, 172.

Coelli TJ (1995). Estimators and hypothesis tests for a stochastic frontier function: a Monte Carlo analysis. J. Productivity Anal.,. 6(3): 247-268.

Coelli TJ, Perelman S (1999). Theory and methodology: A comparison of parametric and non-parametric distance functions: With application to European railways. European J. Oper. Res., 117: 326-339.

Coelli TJ, Perelman S (2000). Technical efficiency of European railways: a distance function approach. Appl. Econ., 32: 1967-1976.

Food and Agriculture Organization (2009). FAOSTAT, Production Statistics.

http://faostat.fao.org/site/567/default.aspx#ancor (accessed April 2009).

Fare R, Grosskopf S, Lovell CAK (1994). Production Frontiers. Cambridge University Press, Cambridge.

Feng S (2008). Land rental, off-farm employment and technical efficiency of farm households in Jiangxi Province, China. Netherland J. Agric. Sci., 55(4): 363-378.

Ferrier GD, Lovell CAK (1990): Measuring cost efficiency in banking: Econometric and linear programming evidence. J. Econ., 46: 229-245.

Haji J (2006). Production efficiency of smallholders' vegetable-dominated mixed farming system in eastern Ethiopia: A non-parametric approach. J. Afr. Econ., 16 (1): 1-27.

Hassine-Belghith NB (2009). Exporting, technical efficiency and product quality: An empirical analysis of the agricultural sector in the Mediterranean Countries. J. Dev. Stud., 45(5): 769-788.

Kalaitzandonakes NG, Dunn EG (1995). Technical efficiency, managerial ability and farmer education in Guatemalan corn production: A latent variable analysis. Agric. Res. Econ. Rev., 24: 36-46.

Khai HV, Yabe M, Yokogawa H, Sato G (2008). Analysis of productive efficiency of soybean production in the Mekong River Delta of Viet Nam. J. Faculty Agric. Kyushu Univ., 53(1): 271–279.

Lundvall K, Battese GE (2000). Farm size, age and efficiency: evidence from Kenyan manufacturing firms. J. Dev. Stud., 36(3):146-163.

Mariano MJ, Villano R, Fleming E, Acda R (2010). Meta frontier analysis of farm-level efficiencies and environmental-technology gaps in Philippine rice farming. Proceedings of the 54th Annual Conference of Australian Agricultural and Resource Economics Society, 10-12 February, Adelaide, Australia.

Msuya EE, Hisano S, Nariu T (2008). Explaining productivity variation among smallholder maize farmers in Tanzania. http://mpra.ub.uni-muenchen.de/14626/ accessed 10.03.2009.

Muhammad IJ (2009). Efficiency Analysis of Cotton-Wheat and Rice-Wheat Systems in Punjab, Pakistan. Unpublished PhD thesis, University of Agriculture, Faisalabad.

Okoye BC, Onyenweaku CE, Asumugh GN (2006). Allocative efficiency of small-holder cocoyam farmers in Anambra State, Nigeria. MPRA Paper No. 17362. http://mpra.ub.uni-muenchen.de/17362/. accessed 12.04.2010.

Okoye BC, Agbaeze, CC, Asumugha, GN, Aniedu, OC, Mbanaso ENA (2009). Small is beautiful: empirical evidence of an inverse relationship between farm size and productive efficiency in small-holder cassava production in Ideato North LGA of Imo State. MPRA paper No. 17418. http://mpra.ub.uni-muenchen.de/17418/ accessed. 12.04.2010.

Oluwatayo IB, Sekunmade AB, Adesoji SA (2008). Resource use effciency of maize farmers in rural Nigeria: Evidence from Ekiti State. World J. Agric. Sci., 4(1):91-99. IDOSI Publications.

Oyewo IO, Fabiyi YL (2008). Productivity of maize farmers' in Surulere Local Government Area of Oyo State. Int. J. Agric. Econ. Rural Dev., 1(2): 25-34.

Peterson WL (1997). Are large farms more efficient? University of Minnesota. http://ideas.repec.org/p/wop/minnas/9702.html. accessed 20.09. 2009.

Seymoun E, Battese G, Fleming EM (1998). Technical efficiency and productivity of maize producers in Eastern Ethiopia: a study of farmers within and outside the Sasakawa-global 2000 project. Agric. Econ., 19(3): 341–348.

Sharma KR, Leung P, Zalleski HM (1999). The technical, allocative, and economic efficiencies in swine production in Hawaii: A comparison of parametric and non-parametric approaches, Agric. Econ., 20: 23-35.

Smith RJ, Blundell RW (1986). An exogeneity test for the simultaneous equation Tobit model with an application to labour supply, Econometrica, 54: 679-685.

United Nations Development Programme (2009). Human Development Report. Overcoming barriers: Human mobility and development. http://hdr.undp.org/en/media/HDR_2009_EN_Indicators.pdf . accessed 26.05.2010.

Wadud A, White B (2000). Farm household efficiency in Bangladesh: A comparison of stochastic frontier and DEA methods. Appl. Econ., 32(13):1665–1673.