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Abstract

Purpose – The purpose of this paper is to estimate production and scale efficiency of maize producing farms in South-Western Nigeria.

Design/methodology/approach – This study is based on a semi-parametric approach and uses a combination of econometrics and linear programming to build two stage Data Envelopment Analysis (DEA) model.

Findings – Model findings shows existence of production and scale inefficiencies in maize production. The study concludes that there is still room for efficiency improvements in the existence of the current maize production technology. It also finds several socio-economic variables such as, off-farm work, education, extension services and credit, which positively impact on technical efficiency of farm households.

Practical implications – Efficiency indicators could be used to monitor resource use efficiency in crop production by local government.

Social implications – Efficiency improvements will increase maize production in the country which in turn reduce social unrest and food insecurity.

Originality/value – This study is one of the first which has employed DEA approach to analyze maize productivity and pioneer in using non-traditional bootstrapping approach to obtain robust efficiency scores in the case of Nigeria.

Keywords Efficiency, Agricultural economies, Developing countries

Paper type Research paper

1. Introduction

Maize crop is the most vital cereal in the world after wheat and rice and one of the widely consumed staple food crops (e.g. can easily be transformed to a variety of bi-products for household consumption) in Nigeria. It is accepted as a major energy source and has higher productivity per man-hour invested among all the cereals. It is grown as sole crop or as in rotation as intercrop with other crops in almost all vegetation zones of Nigeria and its cultivation provides working opportunities and rural livelihoods for the poor. It is as important as sorghum and millet for the country (Ojo, 2000).

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The production of maize is very central to the realization of national food security and achieving higher agricultural growth. It is a commercial crop and is highly demanded as a raw material in agro-industrial sector (Iken and Amusa, 2004). However, it is also subsistence crop and its cultivation even in small lands can feed rural households and reduce hunger. Hence, any negative change in the supply side can drag the country into poverty. Recent trends show the stronger demand force for maize relative to its supply which can be seen from the frequent increase in maize prices (Aye and Mungatana, 2010). According to FAOSTAT (2011), average maize prices in Nigeria were one of the highest in the world over the years 1991-2010 (Figure 1).

Nigeria is ranked the second largest maize producer in Africa after South Africa. Its production in 1990 was 5,768 thousand tons and declined to 4,107 thousand tons in 2000 but increased to 7,306 thousand tons in 2010. The harvested area, however, was constantly falling in this period. It dropped from 5,104 thousand ha to 3,336 thousand ha over the 1990-2010 years (FAOSTAT, 2011). Maize yields relatively increased and currently it is about 2.2 tons ha^{-1}. This is, however, still low if compared to the world average and to those countries which are leading maize producing countries in Africa such as South Africa and Egypt with yields 4.7 tons ha^{-1} and 7.4 tons ha^{-1}, respectively. From the recent trends it can be seen that Nigeria is capable of increasing maize productivity further given the accessible land, labor and other input resources are used efficiently. In this regard increasing production efficiency[1] of resource utilization in maize production has significant policy implication for the national strategies adopted in Agricultural sector which is still a principal sector in Nigeria.

By conducting production efficiency analysis it is possible to illustrate whether harvesting more crops is still viable by improving present input use efficiency. It helps to evaluate whether there is a necessity for further investment in agricultural production and technology or there is still room for obtaining more yields with existing technologies under the current agricultural set. Moreover, by conducting scale efficiency (SE) analysis it is possible to draw a clear picture in terms of farm size and technical efficiency (TE) relationship in crop production. In other words, production efficiency refers to the utilization of production factors in the most efficient way, whereas SE provides information about how optimal maize growing land size should be given the other input resources. This study bases its analysis on input-oriented Data Envelopment Analysis (DEA) (Charnes *et al.*, 1978, 1981). With an input orientation, it is possible to illustrate how much resource endowments can be reduced for a given output level. Since study is also interested investigating some of the factors

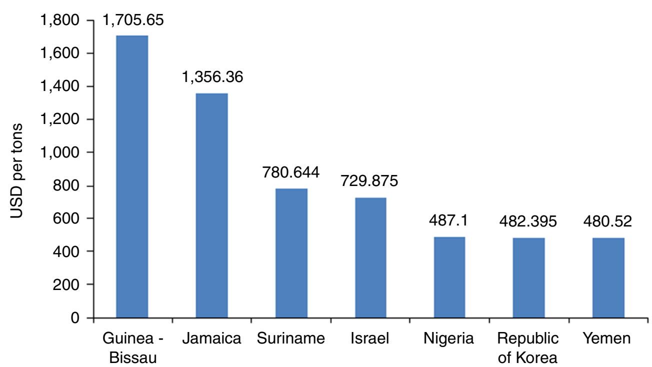

Figure 1.
Top seven countries with highest prices for maize (mean 1991-2010)

which influence maize production efficiency, it follows recent developments in non-parametric frontier modeling.

The paper utilized the sample which is relatively small, thus, efficiency results obtained from DEA model could be biased. While small sample size is not avoidable in the case of developing countries, one way to make results consistent in non-parametric models is to estimate confidence intervals (CIs) for the efficiency scores. It is not possible to derive them analytically; hence, CIs could be constructed by using bootstrapping techniques. The study employed non-naïve bootstrapping approach to provide robust efficiency scores and construct corresponding CIs. The remainder of the paper is divided into five sections. Section 2 reviews the literature in the area of efficiency studies. Section 3 describes the methodology used. Section 4 is devoted to survey design and data description. Section 5 discusses the result. Conclusions and policy implications are given in Section 6.

2. Literature review

The degree of inefficiency in resource utilization and a debate of the causes of efficiency variations took considerable attention in the production and efficiency literature related to developing economies. Wollni and Brümmer (2012) stressed that higher efficiency in resource use would lead to enhancements in overall production and improve farmers' competitiveness. Earlier, Abdulai and Eberlin (2001) emphasized that results from efficiency studies could be very helpful in terms of making better efficiency improving policies. Several African studies which have been conducted in this area (e.g. Alene and Hassan, 2003; Chirwa, 2007; Aye and Mungatana, 2010) also reached the similar conclusions. In terms of methodology, there have been used both non-parametric and parametric approaches to estimate efficiency and to explore efficiency improving indicators. In the case of Nigeria, for example, Aye and Mugatana (2010) showed several empirical approaches in the case of maize producers and demonstrated comparable efficiency levels regardless of the types of methodologies used.

Efficiency analyses are attractive not only because they allow estimation of efficiency levels but also because of their convenience to incorporate efficiency explaining exogenous variables. Although most rural households are engaged in farming activities, the non-farm sector has got extended considerably in the last years, and became ever more important (Oseni and Winters, 2009). Many studies tried to study the relationship between efficiency and farmers' participation in non-farm activities. Previous research shows that small and mono-cropping farms as well as educated farmers are more involved in off-farm business. When a farmer is engaged in off-farm activities, resource use efficiency decreases due to less time spent on – farm production (for similar conclusions see also, e.g. Brummer, 2001; Coelli *et al.*, 2002; Rahman, 2003; Bozoglu *et al.*, 2006; Aye and Mungatana, 2010). A farmer's age and experience was also broadly debated in the efficiency literature. Stefanou and Saxena (1988) found that farm experience had significant positive effects on the efficiency levels (see also, e.g. Kalirajan and Shand, 1985 and Wakili, 2012). Seyoum *et al.* (1998) stated that older farmers were more inefficient. In contrast to that Mathijs and Vranken (2000) and Munroe (2001) found a positive association in samples obtained from Hungarian and Polish farms. Amaza and Maurice (2005), Ajibefun *et al.* (2006) and Wakili (2012) also found similar results in the case of Nigeria.

Moreover, researchers have tried to see whether there is an influence of farmer's education on efficiency levels. Since educated farmers are well aware of ways of obtaining new information, especially with regards to market information and new technologies, it is expected that they would have achieved higher production efficiencies. Ali and Flinn (1989) investigated the role of education in Pakistan on efficiency levels and found significant positive results (for similar findings see also, e.g. Seyoum *et al.*, 1998; Young and Deng, 1999; Mathijs and Vranken, 2000; Wakili, 2012). However, Sotnikov (1998) illustrated that an educational degree in agriculture have not increased the farm managers' ability to use resources efficiently in the case of Russian farms. Dia *et al.* (2010) mentioned that extension agents played important role in educating farmers in maize production in the case of Nigeria. However, Olowa and Olowa (2010) did not find any significant relationship in the same context.

Another important policy variable which influences TE is credit. This was proven in several studies in the previous studies. Abdulai and Eberlin (2001) and Muhammad (2009) found that access to formal credit increased production efficiency. Ahmad *et al.* (2002) stressed that farmers are efficient only if credit is given in advantageous terms. Binam *et al.* (2004) emphasized that extra cash during the growing season was one of the reasons for better resource utilization. Atis (2006) mentioned that credit should be also given for conservation practices which, in turn, would increase the TE. Alemu *et al.* (2009) highlighted that inefficiency could come from using agricultural credit for consumption (see also, e.g. Parry and Carter, 1989). Oladejo and Adetunji (2002) stressed the role of cooperative groups in gaining an access to low rate loans and cooperation among farms.

Extension services also play an important role in crop production. Efficiency studies report mixed results with regards to relationship between TE and extension visits. Aye and Mungatana (2010) found varied results depending on the different models utilized. Ogunyinka and Ajibefun (2004), Okoye *et al.* (2009) and Haji (2006) found negative relationship in the case of Nigeria and Ethiopia. Authors argued that extension agents did not have enough financial resources and skills to help farmers to increase their knowledge and introduce new agronomic practices in the field. International projects were successful in developing and financing extension service organizations. However, sustaining them after the end of the project was not always achievable (see also, Aye and Mungatana, 2010) which required attention of local government.

3. Methodological approach

A DEA approach is developed by Farrell (1957) and its implementation requires use of linear programming techniques which are described by Charnes *et al.* (1978). DEA constructs frontier from best performing farms that is used as a reference group to inefficient farms in the sample. The disadvantage of the method is it does not have a statistical noise attached to it. However, a certain uncertainty level still prevails because of a sampling error. It arises because the DEA chooses the best performing farms from the given sample not from the true population. Thus bootstrapping technique suggested by Simar and Wilson (1998, 2000) must be used to extend the sample size and make it closer to the true population. This work follows homogenous bootstrapping technique developed by Simar and Wilson (1998) to derive robust efficiency indicators and construct corresponding CI.

A DEA is a two-stage approach, in the first stage TE scores are estimated whereas in the second stage, these scores are utilized as dependent variables in the regression model. A Tobit regression could be utilized in the second stage, however, Simar and Wilson (2007) agitated not to use it for several reliable reasons. One of the arguments

Simar and Wilson made is the fact that second stage regression does not have a censored error term but it is more truncated, hence truncated regression is the better econometric model for the analysis.

Taking all these into account, this study constructs the first stage as follows:

$$\hat{t}_i = \min\{\tau \succ 0 | \tau y_i \leqslant \sum_{i=1}^{n} \lambda_i Y; x_i \geqslant \sum_{i=1}^{n} \lambda_i X; \sum_{i=1}^{n} \lambda_i = 1; \lambda_i \geqslant 0, i = 1, \ldots n\} \quad (1)$$

where, $\hat{\tau}_i$ is TE_{vrs} level for each (i) farm household in the sample. y_i and x_i as well as Y and X are denoted as the resource endowments and production matrices of farms and their corresponding sample means, accordingly. λ is an intensity variable which is non-negative. It is used to construct all possible linear combinations of sample observations. Since it is assumed that farmers are not operating under optimal scale, the study uses a VRS (Fare *et al.*, 1983; Banker *et al.*, 1984) technology which assumes variable returns to scale.

As mentioned homogenous bootstrapping approach (for details see Simar and Wilson, 1998) is followed to bootstrap initial efficiency scores. A bootstrapped TE_{vrs} scores are then used in the truncated maximum likelihood regression model in the second stage which can be described as follows:

$$\hat{\tau}_i = z_i \beta + \varepsilon_i \geqslant 1 \quad (2)$$

TE_{vrs} scores are truncated from below 1. z_i is a vector of independent variables that are hypothesized to influence maize production efficiency. ε_i is a continuous and identically as well as independently distributed random variable. It is $N(0, \sigma_\varepsilon^2)$ distributed with left-truncation at $1 - z_i \beta$ for each (i) farm in the sample. It is also independent of z_i. β is a vector of parameters which are estimated by the following maximum likelihood function:

$$L = \prod_{i=1}^{n} \frac{1}{\sigma_\varepsilon} \phi\left(\frac{\hat{\tau}_i - z_i \beta}{\sigma_\varepsilon}\right) \left[1 - \Phi\left(\frac{1 - z_i \beta}{\sigma_\varepsilon}\right)\right]^{-1} \quad (3)$$

$\phi(.)$ and $\Phi(.)$ are the probability density and cumulative distribution functions.

Since, the study is also interested in farm size optimality, it also calculated SE using the following formula:

$$SE = \frac{TE_{crs}}{TE_{vrs}} \quad (4)$$

Here, SE is the scale efficiency. TE_{crs} is the TE under constant returns to scale which is obtained my removing convexity constraint $\left(\sum_{i=1}^{n} \lambda_i = 1\right)$ from Equation (1). When $SE = 1$, scale economy is considered efficient, whereas it is inefficient when $SE < 1$. If interest is to investigate whether SE has decreasing (DRS) or increasing returns to scale (IRS) then TE under non-increasing return to scale (NIRS) must be calculated. NIRS can be calculated by changing the convexity restriction in Equation (1) to $\sum_{i=1}^{n} \lambda_i \leqslant 1$. If $SE < 1$ and VRS $\neq$ NIRS, the farm is said operating under IRS. If $SE < 1$ and VRS = NIRS, farm is said operating under DRS.

4. Data

The focus of this research is on maize – based farming households located in South-Western Nigeria. A cross-sectional primary data is used which was collected through multistage sampling technique. In the first stage, out of the 18 Local Government Areas (LGAs) in Ondo State, Akoko South West and Akoko North East LGAs were purposively selected for the analysis. In the second stage, five communities were randomly selected from each of the selected LGAs using the list of the communities obtained from the Planning Department of the Ondo State Ministry of Agriculture, Forestry and Natural Resources. The selected communities were chosen within the same agro-ecological zone. By this, the study reduced the impact of weather variation on production efficiency. The third stage involved the purposeful selection of nine maize farmers from each of the selected communities. The above sampling design finally generated a total of 90 maize growing farmers which were used for the efficiency analysis. The attention was paid more to the quality of data rather than increasing sampling size. A well-structured questionnaire was adopted to collect data on a wide range of variables which include socio-economic/demographic characteristics, quantity and prices of resource endowments and maize output. Secondary data on farm families in Nigeria, village listing and maize production figure for Ondo state were sourced from the National Bureau of Statistics (NBS) and the Ondo State Ministry of Agriculture, Forestry and Natural Resources.

The study utilized one output and six inputs in the efficiency analysis. Maize output (y) was computed as a total output of maize produced for the given production season which include home consumption, quantity sold or given out as gift and the quantity fed to livestock. It was valued in the monetary terms. The first important input is the labor ($x1$). Following the literature, the labor input was converted to man-hour using labor converting factors. For instance, adult male and female labor was converted using 1 and 0.75, respectively. For children and farmers aged 60 and above converting factor was equal to 0.5. The total labor cost was expressed in monetary units. The second input used in the analysis is fertilizer ($x2$). Since fertilizer in Nigeria is mostly sold in 50 kg bags, the total cost of fertilizer was measured taking this into account. In calculating the current value of farm implements ($x3$), depreciation was also calculated. Seed input costs ($x4$) included seeds purchased from the nearby local market, obtained as a gift as well as produced in the previous season. The land input ($x5$) is measured in ha. Finally, the costs of the prominent agrochemicals ($x6$) usually used for maize production in Nigeria such as herbicides and insecticides were also summed to total cost of chemicals. The summary statistics of these variables are presented in Table I.

Because of small sample size, the study used the most important exogenous variables which are hypothesized to have impact on production efficiency variations among maize producing farms. Summary statistics are given in Table II.

Before conducting efficiency analysis, the study checked for multicollinearity by running Ordinary Least Squares (OLS) regression with all exogenous variables utilized in the truncated regression and calculated variance inflation factor. Results which are described in Table III show that multicollinearity is not a problem in the estimated model and all variables can be included in the final model.

The study utilized the FEAR package developed by Wilson (2008) within the R Project (R Development Core Team, 2009), and Stata 12 statistical software to obtain initial and bootstrapped production efficiency scores from DEA model as well as to estimate truncated regression to investigate impact of exogenous variables on production efficiency of maize farmers.

5. Empirical results and discussion

Input-oriented DEA produces TE scores that are bounded 1 from below. However, the study used inverse of the initial and bias-corrected average TE scores for ease of interpretation (Table IV) which are between 0 and 1.

5.1 TE

The study reported TE under CRS and VRS in the first and second columns, respectively (Table IV). Since the highest TE in resource use is achieved at 1.0, model

Description	Mean	SD	Min	Max
Output				
Maize revenue	61,477.1	86,071.4	10,000	80,000
Inputs				
Labor cost	4,692	6,826	1,250	4,571
Implements cost	1,866	4,914	350	3,429
Chemicals cost	199	506	120	683
Fertilizer cost	794	2,400	0	2,857
Seeds cost	828	1,678	125	2,250
Maize grown area (ha)	2.5	1.2	1	7

Source: Survey results

Table I. Descriptive statistics of variables used in the first stage of the DEA model (ha^{-1})

Description	Unit	Mean	SD
Farming experience of farm household head	years	17.8	12.5
Off-farm work	Dummy (1 = Yes)	0.5	0.5
Educational level of farm household head	Dummy (1 = Higher)	0.2	0.4
Amount of credit	1,000	30.6	57.7
Extension visit	Dummy (1 = Yes)	0.5	0.5
Gender	Dummy (1 = Male)	0.9	0.4

Source: Survey results

Table II. Explanatory variables used in the second stage

Description	Coefficient estimates	SE	*t*-statistics	Collinearity statistics VIF	Collinearity statistics Tolerance
Intercept	0.933	0.032	29.1		
Farming experience of household head	−0.001	0.001	−1.4	1.22	0.82
Off-farm work	−0.042	0.02	−2.11	1.22	0.82
Educational level of household head	−0.037	0.022	−1.7	1.22	0.82
Amount of credit	−0.001	0	−7.26	1.15	0.87
Extension visit	−0.036	0.02	−1.82	1.1	0.91
Gender	0.009	0.027	0.33	1.09	0.92

Table III. OLS estimates of collinearity statistics findings show that there is still opportunity for efficiency increases with existing technologies used in maize production. It can be also observed that similar results are achieved when farms are divided by different land size groups. Lowest TE is achieved by the farms which have maize grown areas between 4 ha and 7 ha. While farms up to 2 ha suffered from scale and technical inefficiencies, farms larger than 2 ha, mostly suffered from technical inefficiencies. Given the minor difference between CRS and VRS technologies with farms that have a maize grown area of more than 2 ha, it can be concluded that most of the productivity gaps arose not from scale differences between farms but rather, from some internal (e.g. mismanagement, delay in doing agronomic activities, farm characteristics) and external factors (locational, institutional, socio-economic) related to maize farming.

The third column in Table IV reports percentage of best performing farms that serve as a reference group and constitute frontier under VRS technology. The fourth column reports bootstrapped efficiency scores which are calculated based on Simar and Wilson (1998). As mentioned to see how biased initial TE_{vrs} results are, homogenous bootstrapping was performed and considerable difference between initial and bootstrapped efficiency scores was found. For example, the initial TE under VRS suggest that farms could reduce their resource endowment costs by 12.4 percent $(((1/0.89)-1) \times 100)$ if achieving full efficiency was a target, whereas the bootstrapped TE levels suggest cost reductions by 20.4 percent $((1/0.83-1) \times 100)$. Columns 5 and 6 are CI for bootstrapped efficiency scores. It can be observed that bootstrapped efficiency levels are smaller than their original ones which signal the initial TE_{vrs} levels are overestimated. The width of the 95 percent CI for TE_{vrs} levels is 0.12, which shows higher statistical variability among bootstrapped TE_{vrs}. Similar findings are observed in other socio-economic environments (e.g. Brummer, 2001; Latruffe *et al.*, 2005; Olson and Vu, 2009).

From Figure 2, it is observed that 52 percent of farms had TE_{vrs} scores more than 90 percent. This indicates that these farms operated under high production efficiency in maize cultivation. However, 21 percent of farms had a TE_{vrs} scores <80 percent. This shows the possibility of high cost savings for these farms if resources are used in an efficient manner.

When farms are ranked from the lowest to highest bootstrapped TE_{vrs}, further insights can be provided to the analysis. Figure 3 shows that the initial TE_{vrs} did not provide a smooth line as it did with the bias-corrected TE_{vrs}. The study also found that variability in the CI existed even with similar efficiency estimates. This was especially true for farms with higher maize land size. It could be postulated that the small-scale farmers were those who have low aptitude for innovation and are thus risk averters. In addition, they may not be resource endowed to try new innovations even when such is within their locality.

Table IV.
Technical efficiency estimates by land area

	Initial TE CRS	Initial TE VRS	Bias corrected TE VRS single	Lower bound 95% CI single	Higher bound 95% CI single	Average width
Mean	0.78	0.89	0.83	0.77	0.88	0.12
1.00-2.00	0.77	0.95	0.88	0.79	0.94	0.15
2.1-3.00	0.82	0.88	0.84	0.78	0.88	0.1
3.1-4.00	0.82	0.86	0.82	0.76	0.86	0.09
<7.00	0.61	0.62	0.59	0.56	0.62	0.06

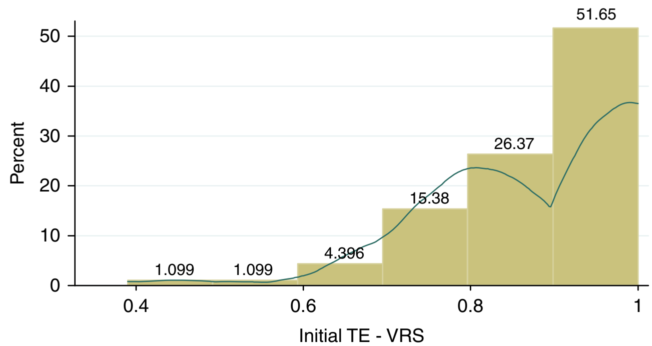

Figure 2. Technical efficiency distribution

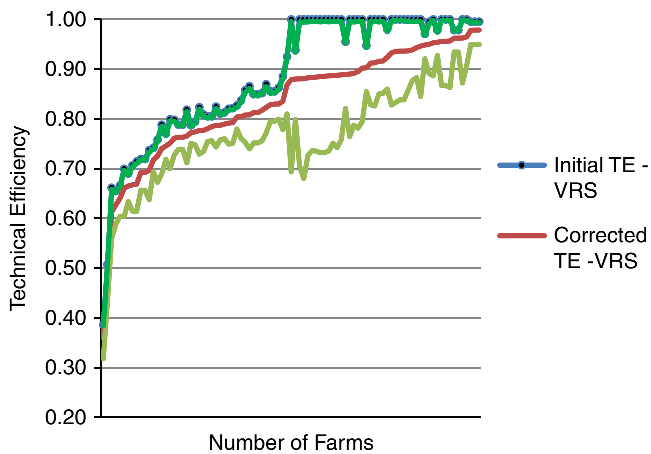

Figure 3. TE distribution with confidence intervals

5.2 SE

The results from SE are reported in Table V which shows percentage of farms operating under different returns to scale. It can be noticed that there is some degree of scale inefficiency among maize producing farms. However, overall SE is 0.88 which is relatively high. From these findings it can be concluded that overall inefficiency is occurring mostly because of technical inefficiency and to some small extent because of SE. This also stems from the poor-resource endowment of the farmers. It is interesting

Table V. Returns to scale indicators

Indicators	Scale efficiency
SE	0.88
SE = 1	14.2
DRS	1.1
IRS	84.6

Source: Model results

to observe that farms that showed some degree of scale inefficiency were operating under IRS technology. This shows underutilization of production factors which also signals maize producers are too small in their farm operations and thus increasing the maize land size may bring increase in maize output. In the long run, this will enable farmers to experience decrease in the cost of production per output (see also, e.g. Ogundari *et al.*, 2006 for similar suggestions).

As seen from Figure 4, SE increased with the enlargement of maize cultivated areas and it is relatively low with farms that have small maize cultivated areas. This is again in conformity with the earlier assertion about over-utilization of input resources in small land areas. A policy recommendation in this regard should be enlarging farm sizes and improving farmers' access to agricultural inputs.

5.3 Truncated regression

The results from the second stage analysis are reported in Table VI. It includes standard errors and CI which makes non-parametric models as attractive as econometric models. Because of the model developed, negative sign in Table VI must be read as factors positively influencing efficiency scores.

The first exogenous variable which showed statistically significant result is off-farm work. This exogenous variable delivers information on time spent for non-farming activities. As shown in Section 2, literature review offers mixed results with regards to whether off-farm engagement increases or decreases production efficiency in crop production. From one point, off-farm work reduces farmer's time spent on farming activities. This, in turn, results in the reduction of efficiency and fall in maize output.

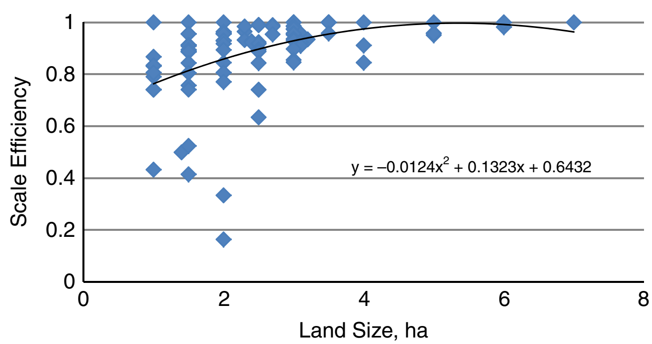

Figure 4.
Scale efficiency and land relationship

Table VI.
Results from truncated regression

	Coefficient estimates	SE	*z*	95% Confidence interval
Intercept	0.9327***	0.0308	30.2900	0.0699 to 0.0937
Farming experience of farm household head	−0.0011	0.0008	−1.4600	−0.0026 to 0.0004
Off-farm work	−0.0416**	0.0190	−2.1900	−0.0788 to −0.0044
Educational level of farm household head	−0.0373*	0.0210	−1.7700	−0.0786 to 0.0039
Amount of credit	−0.0012***	0.0002	−7.5500	−0.0015 to −0.0009
Extension visit	−0.0359*	0.0189	−1.8900	−0.0730 to 0.0013
Gender	0.0090	0.0263	0.3400	−0.0425 to 0.0606

Findings of the current study show that off-farm work has positive impact on TE in maize production. This might be because an additional income which is generated by non-agricultural activities could have been used to purchase inputs (or higher additional labor) during the agricultural season which in turn increased maize production. This is a plausible finding which shows that farmers have been able to diversify their income without reducing efficiency of resource use in maize production.

Findings show that education level of farm household also has positive impact on TE. This is reasonable given the level of involvement in agricultural transformation being put in place by the government presently. A better educated farmers were able to manage maize production efficiently and develop new strategies and practices to get more maize crops from given agricultural land. They had access to agricultural information, used better agronomic practices and developed good networks with local input providing distributors.

Credit variable also has positive impact on TE. Since, access to additional cash allows farmers to hire additional labor and necessary inputs on time and in necessary amounts, this in turn increases maize output. Credit, therefore, can assist farmers to increase TE, while credit constraints decrease the efficiency of farmers by limiting the adoption of high-yielding varieties and the acquisition of information needed for increased productivity. While there exists formal and informal sources of obtaining credit, it is important that to stress that credit is utilized for targeted purposes only. If credit displaces another source of consumption, it will have a zero effect on production efficiency. Another thing is that agricultural credit must have lower interest rates and easy access to it.

Extension visits variable was also positively related with TE. This can be explained by the fact that extension agents were helpful in familiarizing farm households with new technologies and introducing new innovations as well as agronomic practices used in maize production. Since extension agents are also dependent on financial support from the state, policy implications should be toward finding alternative sources to support extension organizations in rural areas. This should be also in parallel with the development of roads, markets and infrastructure.

6. Conclusion and policy implications

The study investigated the TE levels of maize farms in the study area using the DEA methodology in combination with truncated regression. Homogenous bootstrapping approach was utilized to obtain robust efficiency scores. The research found relatively similar efficiency scores as have been reported in the previous studies conducted in Nigeria (e.g. Aye and Mungatana, 2010; Wakili, 2012). Based on the findings, the study concludes that there is still room for efficiency enhancements using available production input and technology. Results obtained from such studies can be used by the local administration at a village, district and provincial level to monitor resource use efficiency in crop production. Findings show that maize farmers are not producing at an optimum level, which could be attributed to the number of circumstances, such as internal inadequacies that arises from mismanagement of productive resources, delay in planting, weeding and application of yield enhancing inputs such as fertilizer. More importantly, production efficiency is highly affected not only by locations such as rural or urban, upland or lowland (Fadama) farm, but also by institutional and socio-economic as well as demographic characteristics. It was revealed that the inefficiency effects among farmers are influenced by farming experience, off-farm work, educational level, amount of credit and extension visits. The empirical evidence also suggests the prevailing economies of scale despite farms in the study area were operating at small-scale lands.

Research implications emphasize the urgent need for proper development strategies, appropriate policy formulation and swift execution of adopted decrees to assist farms to better cope with inefficiencies as this is projected to have further impact on maize productivity growth, poverty reduction and food security. Policy recommendations include strengthening the agricultural extension components of all Agricultural Development Programs in all states of Nigeria. It is also acclaimed that programs and policies that could facilitate prompt and an adequate access to credit should be encouraged and implemented (see also, e.g. Olowa and Olowa, 2010 for similar recommendations). Future policies should be targeted providing agricultural training for farmers and further encouraging rural population to get a better education. If resources are used efficiently, farms increase maize production and satisfy growing needs of population which in turn will have positive societal impact and reduce food insecurity in the country.

Note

1. The study will use production efficiency term interchangeably with technical efficiency and resource use efficiency.

References

Abdulai, A. and Eberlin, R. (2001), "Technical efficiency during economic reform in Nicaragua: evidence from farm household survey data", *Economic systems*, Vol. 25 No. 2, pp. 113-125.

Ahmad, M., Chaudhry, G.M. and Iqbal, M. (2002), "Wheat productivity, efficiency and sustainability: a stochastic production frontier analysis", *Pakistan Development Review*, Vol. 41 No. 4, pp. 643-663.

Ajibefun, I.A., Daramola, A.G. and Falusi, A.O. (2006), "Technical efficiency of small scale farmers: an application of the stochastic frontier production function to rural and urban farmers in Ondo State, Nigeria", *International Economic Journal*, Vol. 20 No. 1, pp. 87-107.

Alemu, B.A., Nuppenau, E.A. and Bolland, H. (2009), "Technical efficiency across agro-ecological zones in Ethiopia: the impact of poverty and asset endowments", *Agricultural Journal*, Vol. 4 No. 4, pp. 202-207.

Alene, A. and Hassan, R. (2003), "The determinants of farm-level technical efficiency among adopters of improved maize production technology in western Ethiopia", *Agrekon*, Vol. 42 No. 2, pp. 1-14.

Ali, M. and Flinn, J.C. (1989), "Profit efficiency among Basmati rice producers in Pakistan Punjab", *American Journal of Agricultural Economics*, Vol. 71 No. 2, pp. 303-310.

Amaza, P.S. and Maurice, D.C. (2005), "Identification of factors that influence technical efficiency in rice-based production systems in Nigeria", Paper presented at Workshop on Policies and Strategies for Promoting Rice Production and Food Security in Sub-Saharan Africa, Cotonou, November 7-9.

Atis, E. (2006), "Economic impacts on cotton production due to land degradation in the Gediz Delta, Turkey", *Land Use Policy*, Vol. 23 No. 2, pp. 181-186.

Aye, G.C. and Mungatana, E.D. (2010), "Technical efficiency of traditional and hybrid maize farmers in Nigeria: comparison of alternative approaches", *African Journal of Agricultural Research*, Vol. 5 No. 21, pp. 2909-2917.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984), "Some models for estimating technical and scale inefficiencies in data envelopment analysis", *Management Science*, Vol. 30 No. 9, pp. 1078-1092.

Binam, J.N., Tonye, J., Nyambi, G. and Akoa, M. (2004), "Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon", *Food Policy*, Vol. 29 No. 5, pp. 531-545.

Bozoglu, M., Ceyhan, V., Cinemre, A., Demiryürek, K. and Kiliç, O. (2006), "Evaluation of different trout farming systems some policy issues in the Black Sea Region Turkey", *Journal of Applied Sciences*, Vol. 6 No. 14, pp. 2882-2888.

Brummer, B. (2001), "Estimating confidence intervals for technical efficiency: the case of private farms in Slovenia", *European Review of Agricultural Economics*, Vol. 28 No. 3, pp. 285-306.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978), "Measuring the efficiency of decision making units", *European Journal of Operational Research*, Vol. 2 No. 6, pp. 429-444.

Charnes, A., Cooper, W.W. and Rhodes, E. (1981), "Evaluating program and managerial efficiency: an application of data envelopment analysis to program follow through", *Management Science*, Vol. 27 No. 6, pp. 668-697.

Chirwa, E.W. (2007), "Sources of technical efficiency among smallholder maize farmers in Malawi", Research Paper No. 172, African Economic Research Consortium, Nairobi.

Coelli, T., Rahman, S. and Thirtle, C. (2002), "Technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation: a non-parametric approach", *Journal of Agricultural Economics*, Vol. 53 No. 3, pp. 607-626.

Dia, Y.Z., Zalkuwi, J.W. and Gwandi, O. (2010), "Economics of scale and cost efficiency in small scale maize production in Mubi North Local Government in Adamawa State, Nigeria", *African Journal of Agricultural Research*, Vol. 5 No. 19, pp. 2617-2623.

FAOSTAT (2011), "FAO Statistics division", available at: http://faostat3.fao.org/home/index.html (accessed November 16, 2011).

Fare, R., Grosskopf, S. and Lovell, C.A.K. (1983), "The structure of technical efficiency", *The Scandinavian Journal of Economics*, Vol. 85 No. 2, pp. 181-190.

Farrell, M.J. (1957), "The measurement of productive efficiency", *Journal of the Royal Statistical Society*, Vol. 120 No. 3, pp. 253-290.

Haji, J. (2006), "Production efficiency of smallholders' vegetable dominated mixed farming system in eastern Ethiopia: a nonparametric approach", *Journal of African Economies*, Vol. 16 No. 1, pp. 1-27.

Iken, J.E. and Amusa, N.A. (2004), "Maize research and production in Nigeria", *African Journal of Biotechnology*, Vol. 3 No. 6, pp. 302-307.

Kalirajan, K.P. and Shand, R.T. (1985), "Types of education and agricultural productivity: a quantitative analysis of Tamil Nadu rice farming", *The Journal of Development Studies*, Vol. 21 No. 2, pp. 232-243.

Latruffe, L., Balcombe, K., Davidova, S. and Zawalinska, K. (2005), "Technical and scale efficiency of crop and livestock farms in Poland: does specialization matter?", *Agricultural Economics*, Vol. 32 No. 3, pp. 281-296.

Mathijs, E. and Vranken, L. (2000), "Farm restructuring and efficiency in transition: evidence from Bulgaria and Hungary", Selected Paper, American Agricultural Economics Association Annual Meeting, Tampa, FL, July 30-August 2.

Muhammad, I.J. (2009), "Efficiency analysis of cotton-wheat and rice-wheat systems in Punjab, Pakistan", unpublished PhD thesis, University of Agriculture, Faisalabad.

Munroe, D. (2001), "Economic efficiency in Polish peasant farming: an international perspective", *Regional studies*, Vol. 35 No. 5, pp. 461-471.

Ogundari, K., Ojo, S.O. and Ajibefun, I.A. (2006), "Economies of scale and cost efficiency in small scale maize production: empirical evidence from Nigeria", *Journal of Social Sciences*, Vol. 13 No. 2, pp. 131-136.

Ogunyinka, E.O. and Ajibefun, I.A. (2004), "Determinants of technical inefficiency on farm production: tobit analysis approach to the NDE farmers in Ondo State, Nigeria", *International Journal of Agriculture and Biology*, Vol. 6 No. 2, pp. 355-358.

Ojo, S.O. (2000), "Factor productivity in maize production in Ondo state", *Nigeria' Applied Tropical Agriculture*, Vol. 15 No. 1, pp. 57-63.

Okoye, B.C., Onyenweaku, C.E. and Asumugh, G.N. (2009), "Allocative efficiency of small-holder cocoyam farmers in Anambra State, Nigeria", *Nigeria Agricultural Journal*, Vol. 38 No. 1, pp. 70-81.

Oladejo, J. and Adetunji, M. (2002), "Economic analysis of maize (zea mays l.) production in Oyo state of Nigeria", *Agricultural Science Research Journals*, Vol. 2 No. 2, pp. 77-83.

Olowa, O.W. and Olowa, O.A. (2010), "Sources of technical efficiency among smallholder maize farmers in Osun State of Nigeria", *Research Journal of Applied Sciences*, Vol. 5 No. 2, pp. 115-122.

Olson, K. and Vu, L. (2009), "Economic efficiency in farm households: trends, explanatory factors, and estimation methods", *Agricultural Economics*, Vol. 40 No. 5, pp. 587-599.

Oseni, G. and Winters, P. (2009), "Rural nonfarm activities and agricultural crop production in Nigeria", *Agricultural Economics*, Vol. 40 No. 2, pp. 189-201.

Parry, M.L. and Carter, T.R. (1989), "An assessment of the effects of climatic change on agriculture", *Climatic Change*, Vol. 15 Nos 1-2, pp. 95-116.

R Development Core Team (2009), *R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing*, Vienna.

Rahman, S. (2003), "Profit efficiency among Bangladeshi rice farmers", *Food Policy*, Vol. 28 No. 5, pp. 487-503.

Seyoum, E.T., Battese, G.E. and Fleming, E.M. (1998), "Technical efficiency and productivity of maize producers in eastern Ethiopia: a study of farmers within and outside the Sasakawa-Global 2000 project", *Agricultural Economics*, Vol. 19 No. 3, pp. 341-348.

Simar, L. and Wilson, P.W. (1998), "Sensitivity analysis of efficiency scores: how to bootstrap in nonparametric frontier models", *Management Science*, Vol. 44 No. 1, pp. 49-61.

Simar, L. and Wilson, P.W. (2000), "A general methodology for bootstrapping in non-parametric frontier models", *Journal of Applied Statistics*, Vol. 27 No. 6, pp. 779-802.

Simar, L. and Wilson, P.W. (2007), "Estimation and inference in two-stage, semi-parametric models of production processes", *Journal of Econometrics*, Vol. 136 No. 1, pp. 31-64.

Sotnikov, S. (1998), "Evaluating the effects of price and trade liberalisation on the technical efficiency of agricultural production in a transition economy: the case of Russia", *European Review of Agricultural Economics*, Vol. 25 No. 3, pp. 412-431.

Stefanou, S.E. and Saxena, S. (1988), "Education, experience, and allocative efficiency: a dual approach", *American Journal of Agricultural Economics*, Vol. 70 No. 2, pp. 338-345.

Wakili, A.M. (2012), "Technical efficiency of maize Farmers in Gombi local government of Adamawa State, Nigeria", *Agricultural Journal*, Vol. 7 No. 1, pp. 1-4.

Wilson, P.W. (2008), "FEAR: a software package for frontier efficiency analysis with R", *Socio-Economic Planning Sciences*, Vol. 42 No. 4, pp. 247-254.

Wollni, M. and Brümmer, B. (2012), "Productive efficiency of specialty and conventional coffee farmers in Costa Rica: accounting for technological heterogeneity and self-selection", *Food Policy*, Vol. 37 No. 1, pp. 67-76.

Young, D. and Deng, H. (1999), "The effects of education in early-stage agriculture: some evidence from China", *Applied Economics*, Vol. 31 No. 11, pp. 1315-1323.

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