# Technical Efficiency Analysis of Smallholder Maize Farmers in North Eastern Nigeria

**Muhammad Auwal Ahmed**[1, 2]
[2]Department of Agricultural Economics and Extension, Modibbo Adama University of Technology, Yola, Adamawa State, Nigeria
Email: auwalyounky@gmail.com

**Zainal Abidin Mohamed**
[1]Department of Agribusiness and Information Systems, Faculty of Agriculture, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia
Email: zainal.mohamed@gmail.com

**Nolila Mohd Nawi**
[1]Department of Agribusiness and Information Systems, Faculty of Agriculture, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia
Email: nolila@upm.edu.my

**Abdullahi Illiyasu**
[1]Department of Agribusiness and Information Systems, Faculty of Agriculture, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia
Email: manawaci1@gmail.com

**Abstract**

This paper evaluates the level of technical efficiency among smallholder maize farmers as well as the determinants of technical inefficiency in Nigeria using descriptive analysis; slacks-based measure (SBM) of efficiency model, slacks based super-efficiency (SBSE) model and ordinary least square (OLS) model. Data were collected from 300 respondents from four states in Nigeria using a well-structured questionnaire and verbal interviews. Results show that the mean technical efficiency of the farms was 0.69, which is below the frontier technology. This implies that there is a large scope for technical efficiency improvement by about 0.31 with the same set of resources. SBM of efficiency result suggests that if all farms in the study area were to be fully efficient (have zero slacks); the total inputs used by the farmers would be reduced by 29.10% per hectare. The SBSE estimates of the farms ranges from 1.01 to 1.98, and are considered as the most-efficient farms which utilized inputs optimally. Findings from OLS analysis indicates that family size, farming experience, extension contact and education level increases technical efficiency, while age and non-farm activities reduces technical efficiency in maize farming. Thus, government in alliance with extension agents should educate the farmers on the required input quantities to use on their farms during production process. These could enhance their efficiency and output levels which can lead to reduction in input wastage and consequently increase their income level.

**Keywords:** Efficiency, SBM Model, SBSE model, Maize farmers, Nigeria.

*Corresponding Author: auwalyounky@gmail.com

## 1. Introduction

Maize (*Zea mays* L) is one of the most consumed cereals in Nigeria among households of different wealth during the past two decades along with rice, sorghum and millet (FAO, 2013). The quantified worldwide maize output was approximately 1.022 billion tons in 2014, which recorded a slight increase of about 3.7

million tons as compared to the year 2013. America is the largest producer of maize with an average output of 527 million tons in the year 2014. This is followed by Asia who produced a total output of 305 million tons, Europe (113 million tons); Africa produced about 78 million tons respectively (FAO, 2015).

Maize is a significant staple food for more than 1.2 billion individuals in Sub-Saharan Africa and Latin America and a key feed crop in Asia. More than 116 million tons of maize is consumed globally (FAO, 2015), Lesotho has the highest per capita consumption with about 174kg per year. Eastern and Southern Africa uses 85% of its output as food, while the entire Africa uses 95% of its output and imports 28% from other continents. Nigeria is the foremost maize producer in West Africa with about 49.90% and 55.26% of the total output obtained in 2013 and 2014 respectively. Ghana recorded about 10.45% and 9.02%; Mali documented 8.90% and 8.93%, Burkina Faso (9.39% and 7.34%) and others (21.36% and 19.45%) respectively.

Despite its importance, maize output per hectare is still low averaging only 2.0 metric tons at against the projected average output of 5.1 metric tons per hectare (Ibrahim et al., 2014). The low level of output was attributed to challenges confronting farmers in managing their farms and these challenges include Poor extension services, low investment in research, lack of credit facility, poor seeds and seedlings, late delivery of fertilizer to farmers, floods, prolonged drought, weed related yield losses, declining soil fertility, lack of agrochemicals, farmers' experience, age of the farmers, educational level of farmers, non-farm activities, family size, farm size and adaptation of improved techniques might be responsible for the technical inefficiency at the farm level (NBS, 2013).

A study on production efficiency will enable smallholder farmers to identify their capabilities, prospects and the specific factors responsible for technical inefficiency in the study area. Also, it can assist farmers in understanding the inputs that are under-utilized or over utilized during production process and the possible adjustment in order to increase efficiency in the future through better farm planning and management. The findings of the study can be used by government and private sectors to enact new policies that can aid in improving this essential sector. It is against this background that this study estimates the level of technical efficiency among maize farmers and evaluates the factors that influence inefficiency in the farming practices.

The study of productive efficiency started with the pioneering works of Farrell (1957). Farrell defined efficiency by comparing the actual achievable value of the objective function against what is obtained at the frontier. A producer is only efficient if he/she achieves their objectives and inefficient if he/she fails to achieved their objectives. Efficiency has numerous dimensions among which are technical efficiency, allocative efficiency and economic efficiency. Technical efficiency (TE) is defined as the ability to achieve a high level of output given a similar level of production inputs (Coelli et al., 1998). According to Battese and Coelli (1995), Technical efficiency is related with the behavioral goals of output maximization. Technical efficiency deals with efficiency in respect to factor- product transformation (Esparon and Sturgess, 1989). A technically efficient firm/farm has to produce at the production frontier level. Nevertheless, this is always contrary due to chance factors such as institutional, environmental, farm specific factors and farmer characteristics which lead to producing below the expected output frontier (Battese and Coelli, 1995).

Many empirical studies have estimated the efficiency of various enterprises, but only a few focused on maize production. Esham (2014) examined technical efficiency of maize production by smallholder farmers in the Moneragala district of Sri Lanka and found out that the mean technical efficiency of the farmers was 72%, while Addai and Owusu (2014) indicated that the mean technical efficiency of maize farms across savannah, forest, and transitional agro ecological zones of Ghana was 64%. Ahmed et al., (2014) also estimated technical efficiency of smallholder maize farmers in central rift valley of Ethiopia and their results indicate that farmers attained a mean technical efficiency of 88%.

Similarly, Essilfie et al., (2011) estimated farm level technical efficiency of small scale maize farming in the Mfantseman Municipality of Ghana and discovered that the farmers had attained a mean technical efficiency of 58% whereas Ayinde et al. (2015) examines technical efficiency of maize production in Ogun State, Nigeria and reported a mean technical efficiency of 69%. Ibrahim et al. (2014) estimated the mean technical efficiency of maize production in southern guinea savannah, northern guinea savannah and Sudan savannah as 86.7%, 83.4% and 83.8% respectively.

However, none of these studies operated at the frontier technology (technically efficient) but rather indicated that a considerable level of inefficiency exists in maize production and that farmers need to improve their efficiency levels by utilizing resources optimally.

## 2. Methodology

This section presents the sampling technique, data collection process and the models involved in data analysis.

### 2.1. Sampling method

Adamawa, Bauchi, Gombe and Taraba states were purposively selected based on their prominence in maize production activities in north eastern Nigeria. Two local government areas (LGAs) were further selected from each state based on the prominence of maize production. The lists of maize farmers were collected from the corresponding states' agricultural development projects of the selected LGAs. Finally, the respondents were then selected from the lists using simple random sampling technique.

### 2.2. Data collection

Questionnaire was used as an instrument to gather information and data on the socio-demographic characteristics of the farmers, inputs and output used during single production season. A total of 300 questionnaires were finally distributed to the selected maize farmers, but only 256 questionnaires were correctly completed and recovered from the respondents.

### 2.3. Analytical technique

Slacks-based measure (SBM) of efficiency, slacks based super-efficiency (SBSE) and ordinary least squares (OLS) models were used for the analysis. SBM model was used to estimate the technical efficiency levels as well as input slacks. The technical efficiency estimates were regressed against socio-economic factors, institutional and farm specific factors. SBM model gives better and more reliable results than SFA model that used translog function or Cobb-Douglas production function and the traditional DEA (Tone, 2001). SBSE model was used to analyze super-efficient farms and the super-slacks related with maize farms as suggested by (Tone, 2002).

Although most of the preceding studies used Tobit regression model [Sihlongonyane et al., (2014), Ibrahim et al., (2014), Alam (2011), Casu & Molyneux (2003), Kaliba et al., (2007)], McDonald (2009) argued that the use of such model is inappropriate in this situation. According to McDonald (2009), technical efficiency estimates are fractions and not generated by a censoring process and therefore, he suggested the use of OLS regression model as the most appropriate in this regard. This argument was however, supported by Banker and Natarajan (2008). They reported that the use of OLS regression model in the second stage of DEA gives better results. Thus, the inputs and output variables used to estimate SBM and SBSE models above are presented below:

Maize output/hectare (kg)
Fertilizer used/hectare (kg)
Quantity of seeds/hectare (kg)

Labour (man-days)/hectare
Agrochemicals used (liters)/hectare

### 2.4. Models specification

#### 2.4.1. Slacks-based measure (SBM) of efficiency model

The SBM input-oriented model following Tone (2001), the model is expressed as follows:

$$\ell_1 = \min \; 1 - \frac{1}{w} \sum_{i=1}^{w} \frac{s_i^-}{q_{i0}} \qquad (1)$$

Subject to; $q_{i0} = \sum_{i=1}^{w} q_{in}\lambda_n + s_i^-$ (i = 1,. . . , w),

$$h_{r0} = \sum_{n=1}^{u} h_{nr}\lambda_n - s_r^+ \quad \text{(n = 1 . . . u),}$$

$$\lambda_j \geq 0, \; S_i^- \geq 0, \; S_r^+ \geq 0.$$

2.4.2 Slacks based super-efficiency Model following Tone (2002), Chen (2004). The model can be expressed as follows:

$$\delta_I^* = \min \; \frac{1}{w} \sum_{i=1}^{w} \frac{\bar{q}_i}{q_{i0}}, \qquad (2)$$

Subject to: $\bar{q}_i \geq \sum_{i=1, i\neq 1}^{w} q_i\lambda_i$ (i = 1 . . . w),

$$\bar{y}_r \leq \sum_{i=1, i\neq 1}^{w} y_r\lambda_i \quad \text{(r = 1 . . . s),}$$

$$\bar{q}_i \geq q_{i0}, \; \bar{y} \leq y_o \; \lambda \geq 0.$$

Ordinary Least Squares Model (OLS) followed by Banker and Natarajan (2008), McDonald (2009). The model is expressed in its explicit form as follows:

$$Y_i = \lambda_0 + \sum_{j=1}^{k} \lambda_j Z_{ij} + \mu_i \qquad (3)$$

Variables used in OLS model are presented as follows:
Yi = technical inefficiency estimates
$Z_1$ = non-farm activities
$Z_2$ = educational level
$Z_3$ = family size

$Z_4$ = age
$Z_5$ = experience
$Z_6$ = extension contact
$Z_7$ = access to credit
$\lambda_0$ - $\lambda_j$ are parameters to be estimated
$\mu_i$ = error term

## 3. Results and discussion

### 3.1. Estimates of technical efficiency

The study estimated input-oriented VRS Model efficiency scores of maize farms using SBM approach (Table 1). The technical efficiency of maize farms was estimated in order to develop comprehensive analysis of the industry's performance. The estimated mean value of the farms was 0.69. Based on these findings, the farms were not operating at the technically efficient level (100%). This implies that maize farmers in the sample could reach full technical efficiency by increasing their output by another 31% with the present level of technology and resources. The results support the findings of Hao & Chou (2005), Alene & Hassan (2006) where they reported similar technical efficiency estimates.

**Table 1: Estimated technical efficiency scores of the farms**

| Efficiency scores range | Frequency | Percent |
|---|---|---|
| 0.41 – 0.50 | 5 | 1.95 |
| 0.51 – 0.60 | 33 | 12.89 |
| 0.61 – 0.70 | 82 | 32.03 |
| 0.71 – 0.80 | 57 | 22.27 |
| 0.81 – 0.90 | 73 | 28.52 |
| 0.91 – 1.00 | 6 | 2.34 |
| **Total** | **256** | **100.00** |
| Mean | 0.69 | |
| Minimum | 30 | |
| Maximum | 1.00 | |

Source: field survey, 2015.

### 3.2. Slacks variables analysis

A slack variable is basically defined as the excess input(s) used in the firm/farm production process which is measured as a percentage. The calculated percentages of agrochemicals, seeds, labour, and fertilizer slacks were 1.88, 2.87, 2.73 and 21.62 respectively. The result signifies that if the farmers were to operate efficiently (i.e. have zero inputs slacks), the present inputs level should be reduced by about 1.88%, 2.87%, 2.73% and 21.62% respectively (Table 2). Maize farmers in the study area are smallholders and are unaware of the recommended quantities of input to apply. Therefore, they generally depend on their experience to perform their production activities which results to inefficient use of their farm inputs. The consequence of over utilization of inputs increases the production costs which attracts low profit for farmers and ultimately low standard of living. Hence, the farmers need little adjustments in their use of production inputs in order to operate on the frontier technology.

**Table 2: Slacks variables obtained from the farms**

| **Inputs** | **Slacks (%)** | **Frequency** |
|---|---|---|
| Fertilizer | 21.62 | 92 |
| Seeds | 2.87 | 76 |
| Labour | 2.73 | 54 |
| Agrochemicals | 1.88 | 43 |
| **Total** | **29.10** | **-** |

Source: field survey, 2015.

### 3.3. Slacks based super-efficiency analysis

Efficiency models developed by Charnes et al., 1978; Cooper et al., 2000, have revealed that the optimum efficiency scores that can be obtain by DMUs is denoted by 1.00. To differentiate among these efficient DMUs require super-efficiency analysis with efficiency estimates of more than one as presented in Table 3. The results shows that 59.10% of farms had super-efficiency range of 1.01–1.25, 4.50% ranges from 1.26–1.50 while, 22.70% ranges between super-efficiency scores of 1.51–1.75 and only 13.60% ranged from 1.76–1.98. The minimum super-efficient scores obtained by NCB farms were 1.01 and a maximum of 1.98. The super-efficiency scores define those farms that used proper inputs quantities on their farms during the period of production.

**Table 3: Slacks based super-efficiency scores of the farms**

| SE Range | Frequency | Percent |
|---|---|---|
| 1.01 – 1.25 | 13 | 59.10 |
| 1.26 – 1.50 | 1 | 4.50 |
| 1.51 – 1.75 | 5 | 22.70 |
| 1.76 – 1.98 | 3 | 13.60 |
| **Total** | **22** | **100.0** |
| Minimum | 1.01 | |
| Maximum | 1.98 | |

Source: field survey, 2015.

**3.4. Technical inefficiency analysis**

Table 4 shows the determinants of technical inefficiency in maize production. The study used technical inefficiency scores of maize farmers as the dependent variable. The independent variables with a negative sign will contribute to technical efficiency whereas those with a positive sign, otherwise. The findings indicate that family size, farming experience, extension contact, education level and access to credit increases technical efficiency, while age and non-farm activities reduces technical efficiency in maize farming.

The coefficient of family size has a negative sign and is statistically significant. Maize farmers in most rural areas are poor and mostly depend on manual labour to produce their crops. Therefore, family size with more number of dependents has the tendency to be technically efficient in respect to inputs used. This result support the findings of Begum et al., (2010) where they also revealed that large family size reduces technical inefficiency in farming. Coefficient of farming experience was found to be negative and statistically significant. This means that farmers with more years of farming experience are more likely to be efficient as they have learned more skills over time than their inexperience counterparts. This is supported by Alam (2011), who also found similar results.

The negative coefficient of education variable implies that maize farmers with a higher level of education are likely to be more technically efficient. This result is in conformity with the findings of Tan et al., (2011) who also revealed that farmers having more years of education tend to be more efficient than their non-educated counterparts. The coefficient of credit was estimated to be negative and statistically significant. This means that farmers who have access to credit are inclined to be more efficient than those who do not have access to credit. This may be due to the influence of credit in purchasing adequate production inputs and also in financing farming activities which in turn improved the productivity and income of the farmers at the end of production season. The result supports the findings of Nyagaka et al. (2010) who observed that access to credit increases resource use efficiency.

The coefficient of age variable is positive and statistically significant. This indicates that as the farmers grow older, their technical inefficiency also increases. This could be due to the fact that most of the activities conducted in maize farming are labour demanding. Therefore, the more a farmer grows older, the less productive they becomes in carrying out such operations. However, the result agrees with the findings of Begum et al., (2013) who also found out that age influenced technical inefficiency among farmers. The findings of this study are in consistent with most previous studies.

**Table 4: Determinants of technical inefficiency in maize production**

| Variables | Coefficient | Std. Error | T-value | P-value |
|---|---|---|---|---|
| Constant | -0.304849 | 1.782031 | -0.17 | 0.8692$^{NS}$ |
| Credit | -0.755906 | 0.279350 | -2.71 | 0.0267** |
| Non-farm activities | 0.764509 | 0.689241 | 1.11 | 0.2992$^{NS}$ |
| Education | -1.453492 | 0.380529 | -1.82 | 0.1063$^{NS}$ |
| family size | -0.356076 | 0.135275 | -2.63 | 0.0302** |

| | | | | |
|---|---|---|---|---|
| Age | 0.169417 | 0.038348 | 4.42 | 0.0022* |
| Experience | -0.546307 | 0.126326 | -4.32 | 0.0025* |
| Extension contact | -0.308428 | 0.719903 | -0.43 | 0.6785[NS] |

**Note:** * and ** denotes 0.01% and 0.05% levels of significance.
**NS** denotes insignificant variables.

## 4. Conclusion

This paper evaluates the level of technical efficiency among smallholder maize farmers in Nigeria using SBM model and SBSE model and the results were reported accordingly. In general, the findings of technical efficiency revealed that all the maize farms under study were not producing at the frontier technology. This necessitates the analysis on causes of technical inefficiency by considering some socio-economic characteristics of the farmers, specific factors of the farms and institutional variables. The result from SBSE model reveals that despite the inefficiency, some 22 farms are super-efficient. The findings revealed that access to credit, family size, farming experience, education level and extension contact bears negative signs and hence contributes to technical efficiency while, non-farm activities and farmers' age contributes to technical inefficiency in maize farming.

Furthermore, fertilizer, agrochemicals, seeds and labour inputs used during the production season comprised of slacks which must be reduced accordingly. Based on these findings, Experienced and educated farmers should motivate their inexperience and uneducated counterparts via training and organizing of workshops to share their knowledge in order to boost their farming skills. Also, government in alliance with extension agents should educate the farmers on the required input quantities to use on their farms during production process. These could enhance their efficiency and output levels which can lead to reduction in input wastage and consequently increase their income level.

However, this paper investigated technical inefficiency determinants in maize farming by using only seven variables. Hence, future research should consider factors such as seed quality, farm size, floods, distance to farm area, declining soil fertility, distance to market, marital status, access to government subsidies and adaptation of new innovations as these may influence technical inefficiency. In spite of its limitations, this study still contributes to the existing literatures on technical efficiency in maize production.

## References

Addai, K. N., and Owusu, V. (2014). Technical Efficiency of Maize Farmers across Various Agro Ecological Zones of Ghana. *Journal of Agriculture and Environmental Sciences,* 3(1), 149-172.

Alam, F. (2011). Measuring technical, allocative and cost efficiency of pangas (Pangasius hypophthalmus: Sauvage 1878) fish farmers of Bangladesh. *Aquaculture Research,* 42(10), 1487-1500.

Alene, A. D., & Hassan, R. M. (2006). Erratum: The efficiency of traditional and hybrid maize production in Eastern Ethiopia: An extended efficiency decomposition approach. *Journal of African Economies*, *15*(2), 91-116.

Ayinde, I. A., Aminu, R. O., and Ibrahim, S. B. (2015). Technical efficiency of maize production in Ogun State, Nigeria. *Journal of Development and Agricultural Economics,* 7(2), 55-60.

Banker, R.D., Natarajan, R., (2008). Evaluating contextual variables affecting productivity using data envelopment analysis. Oper. Res. 56, 48–58.

Battese, G. E., and Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics*, 20(2), 325-332.

Begum, M. S. T., Hossain, M. I., & Papanagiotou, E. (2013). Technical efficiency of shrimp farming in Bangladesh: An application of the stochastic production frontier approach. *Journal of the World Aquaculture Society*, *44*(5), 641-654.

Casu, B., & Molyneux, P. (2003). A comparative study of efficiency in European banking. *Applied Economics*, 35(17), 1865-1876.

Coelli, T. J., Rao D. S. P., and Battese, G. E. (1998). *An Introduction to Efficiency and Productivity Analysis*. Kluwer Academic Publishers, Boston, Dordrecht/London, pp. 134-249.

Esham, M. (2014). Technical Efficiency and Determinants of Maize Production by Smallholder Farmers in the Moneragala District of Sri Lanka. *Mediterranean Journal of Social Sciences,* 5(27), 416-422.

Esparon, N. M., & Sturgess, N. H. (1989). The Measurement of Technical Efficiency Using Frontier Production Functions of Rice Farms in West Java 1. *Bulletin of Indonesian Economic Studies,* 25(3), 99-119.

Essilfie, F. L., Asiamah, M. T., and Nimoh, F. (2011). Estimation of farm level technical efficiency in small scale maize production in the Mfantseman Municipality. *Journal of Development and Agricultural Economics,* 3(14), 645-654.

FAO Statistical Year Book (2013). Food and Agriculture Organization of the United Nations, Rome available at www.fao.org/publication

FAOSTAT. (2015). A database of the Food and Agriculture Organisation of the United Nations (FAO). Retrieved February, 2015 from http://faostat.fao.org.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*, *120*(3), 253-290.

Hao, J. C., & Chou, L. Y. (2005). The estimation of efficiency for life insurance industry: The case in Taiwan. *Journal of Asian Economics,* 16(5), 847-860.

Ibrahim, K., Shamsudin, M. N., Yacob, R., and Radam, A. B. (2014). Technical Efficiency in Maize Production and its Determinants: A Survey of Farms Across Agro Ecological Zones in Northern Nigeria. *Trends in Agricultural Economics*, *7*(2), 57-68.

Kaliba, A. R., Engle, C. R., & Dorman, L. (2007). Efficiency change and technological progress in the US catfish-processing sector, 1986 to 2005. *Aquaculture Economics & Management*, *11*(1), 53-72.

McDonald, J. (2009). Using Least Squares and Tobit in Second Stage DEA Efficiency Analyses. *European Journal of Operational Research*, *197*(2), 792-798.

National Bureau of Statistics (NBS), Abuja-Nigeria (2013). Q1 2013-Gross Domestic Product for Nigeria. www.nigerianstat.gov.ng 1-15.

Nyagaka, D. O., Obare, G .A., Omiti, J. M., and Nguyo, W. (2010). Technical efficiency in resource use: Evidence from smallholder Irish potato farmers in Nyandarua North District, Kenya. *African Journal of Agricultural Research*, 5(11), 1179-1186.

Sihlongonyane, M. B., Masuku, M. B., & Belete, A. (2014). Economic Efficiency of Maize Production in Swaziland: The Case of Hhohho, Manzini and Shiselweni Regions. *Research in Applied Economics*, *6*(3), 179-195.

Tan, R. L., Garcia, Y. T., Dator, M. A. L., Tan, I. M. A., & Pemsl, D. E. (2011). Technical efficiency of Genetically Improved Farmed Tilapia (GIFT) cage culture operations in the lakes of Laguna and

Batangas, Philippines. *Journal of ISSAAS (International Society for Southeast Asian Agricultural Sciences)*, *17*(1), 194-207.

Tone, Kaoru (2001). A slacks-based measure of efficiency in data envelopment analysis. European journal of operational research, 130(3), 498-509.

Tone, K. (2002). A strange case of the cost and allocative efficiencies in DEA. *Journal of the Operational Research Society*, *53*(11), 1225-1231.