

# IDENTIFICATION OF FACTORS THAT INFLUENCE TECHNICAL EFFICIENCY IN RICE-BASED PRODUCTION SYSTEMS IN NIGERIA<sup>1</sup>

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## Abstract

*This paper investigates factors that influence technical efficiency in rice-based production systems among fadama farmers in Adamawa State, Nigeria. Primary data were used in the analysis of data. The analytical tools include descriptive statistics and stochastic frontier production function, which incorporates technical inefficiency model using the maximum-likelihood estimation (MLE), applied on a cross-sectional data of 122 sampled farmers during 2002/2003 cropping season. The results show that rice sole crop, rice-maize and rice-cocoyam were the common cropping patterns adopted by farmers. The MLE estimates of the parameters of the stochastic frontier production function reveals that the elasticities of output with respect to land (0.157), seeds (0.146) and other costs (0.382) were significant at ( $p = 0.01$ ), while fertilizer (0.172) and water (0.082) were significant at ( $p = 0.05$ ). The inefficiency model reveals that farming experience and education significantly affect farmers' efficiency levels. Technical efficiencies vary widely among farms, ranging between 0.26 and 0.97 and a mean technical efficiency of 0.80. The economic implication of the study is that efficiency in rice production among fadama farmers in Adamawa State could be increased by 20 percent through better use of available resources, given the current state of technology. This can be achieved through policy interventions that contribute to better access to: improved seeds, irrigation water, fertilizer and farmer-specific efficiency factors, which include enhanced farmer education.*

## 1. Introduction

Agricultural growth in Nigeria is increasingly recognized to be central to sustained improvement in economic development. The sector plays a very significant role in the food security, poverty alleviation and human development chain. However, in more recent years, there has been a marked deterioration in the performance of Nigeria's agriculture. The contribution of agriculture to the gross domestic product (GDP) which stood at an average of 56 percent in 1960-64 declined to 47 percent in 1965-69 and a further decline to 35 percent in 2002-2004.

Rice (*Oryza sativa*) is a major cereal crop in Nigeria. Being as important staple food of many households, rice production in Nigeria rose from 2.4 million metric tonnes in 1994, to 3.1 million metric tonnes in 2002, representing 29.2% rise in domestic production (Table 1). However, despite the rise in domestic production, the demand/consumption of rice far exceeds local production, precipitating an increase in the rice importation bill to as high as US \$160 million in 2003 (FAO, 2003).

**Table 1:** Nigeria's Domestic Output of Rice

Years	Total Area Cultivated (ha)	Total Output (MT)
1994	1,714,000	2,427, 000
1995	1,796,000	2,920, 000
1996	1,784, 000	3,122, 000
1997	2,048, 000	3,268, 000
1998	1,760, 000	3,275, 000
1999	1,763, 000	3,277, 000
2000	1,780, 000	3,298, 000
2001	1,770, 000	2,752, 000
2002	1,699, 000	3,192, 000

Source: FAO (2003).

Production of rice in Nigeria is mainly in the hands of small-scale farmers who are still using unimproved farming techniques. Actual yields<sup>2</sup> of rice differ significantly from potential yields, and this has been attributed to low resource productivity (Federal Ministry of Agriculture of Agriculture, 1995). The implication is that there is a scope for additional increase in domestic

<sup>2</sup> Average yield of 1100 kg/ha was reported for 2001-2003 (FAO, 2003)

output from existing hectares if efficiency of rice production is improved. Since increased output and productivity are directly related to production efficiency, the study becomes imperative, as it would identify factors that influence technical efficiency in rice-based production systems among *fadama* farmers. The identification of those factors, which influence the level of technical efficiency, is a valuable exercise because the factors are significant for policy formulation.

## 2. The concept of technical efficiency

Technical efficiency in production is defined as the ability of the farmer to produce at the maximum output (frontier production), given quantities of inputs and production technology (Aigner, *et al.* 1977). Production efficiency is concerned with the relative performance of the process used in transforming inputs into output. The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources or certain level of output at least-cost. The greater the ratio of production output to the factor input, the greater the magnitude of technical efficiency and vice versa.

This definition of technical efficiency implies that differences in technical efficiency between firms exist. Variation in technical efficiency of producers might arise from managerial decisions and specific-farm characteristics that affect the ability of the producer to adequately use the existing technology.

## 3. Methodology

### 3.1 Study area

The Study area is Adamawa State, located in northeast Nigeria between latitude  $7^{\circ} 33' N$  and  $11^{\circ} 30' N$  and longitude  $9^{\circ} E$  and  $14^{\circ} E$ . It shares common boundaries with the republic of Cameroon in the east and the south, Taraba State in the west, Borno and Gombe States in the north. The State has a projected population of 2,878,014<sup>3</sup>, and a land area approximately 42,159 square kilometers out of which about 226,040 hectares is under cultivation (Adamawa ADP, 1996). Out of the cultivated land, approximately 400 hectares is irrigated. There are approximately 233,425 farming families in the state with an average of seven (7) persons per family. The World Bank has reported that there are about 497,500 hectares of *fadama* lands located in the State, constituting about 15.8% of the total *fadama* lands in the country (World Bank, 1991).

The study used primary data based on 2003 farming season (November, 2002 to June, 2003), which were obtained from the administration of structured questionnaires to a random sample of one hundred and twenty two dry season *fadama* farmers who are into rice-based production. Purposive sampling technique was used in selecting two out of the four zones of the State Agricultural Development Programme (ADP), based on the availability of many flood plains that encourages dry season rice production.

Data collected were analyzed using descriptive statistics and stochastic frontier production function.

### 3.1 Stochastic frontier production function in efficiency studies

The modeling and estimation of production efficiency of a farm relative to other farms or to the 'best' practice in an industry has become an important area of economic study. Much empirical work has focused on imperfect, partial measures of productivity, such as yield per hectare or output per unit of labour (Coelli and Battese, 1996). However, Farrell (1957) suggested a method of measuring technical efficiency of a firm in an industry by estimating the production function of firms, which are fully efficient (i.e. frontier production function).

The study utilized stochastic frontier production function with multiplicative disturbance term following Aigner *et al.* (1977) and Meeusen and van de Broeck (1977) to analyze the data.

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<sup>3</sup> estimated at 2.8% population growth rate based on 1991 population census

This was further improved and used by Battese and Coelli, 1995; Amaza and Olayemi, 2002; Helfand, 2003; and Maurice, 2004. The model used for the study is specified as follows:

$$Y = f(X_a; \beta) \varepsilon \dots\dots\dots (1)$$

Where:

- Y = the quantity of agricultural output (rice);
- X<sub>a</sub> = vector of input quantities;
- β = vector of parameters; and
- e = error term

Where ε is a stochastic disturbance term consisting of two independent elements u and v, where:

$$\varepsilon = u + v \dots\dots\dots (2)$$

The symmetric component, v, account for random variation in output due to factors outside the farmer's control, such as weather and diseases. It is assumed to be normally, independently and identically distributed as N~ (0, σ<sup>2</sup>v). A one-sided component u ≤ 0 reflects technical inefficiency relative to the stochastic frontier, f (X<sub>a</sub>; β) εε. Thus, u = 0 for a farm output which lies on the frontier and u < 0 for one which is below the frontier as | N~ (0, σ<sup>2</sup>u) |; hence, the distribution of u is half-normal.

Measure of technical efficiency for each farm was calculated as:

$$TE = \exp. [E \{U/\varepsilon\}] \dots\dots\dots (3)$$

The Battese and Coelli (1995) single-stage model was applied in the efficiency analysis. In this regard, u in equation 3 is a non-negative random variable, which is the efficiency associated with technical inefficiency factors in production by the sample farmers. It is assumed that the inefficiency factors are independently distributed and that u arises by the truncation (at zero) of the normal distribution with mean μ and variance σ<sup>2</sup>, where u in equation 3 is defined as:

$$U = f(Z_b; \delta) \dots\dots\dots (4)$$

Where: Z<sub>b</sub> is the vector of farmer-specific factors, and  
δ is the vectors of parameters.

The β- and δ- coefficients in equations 1 and 3 respectively are unknown parameters which are expressed in terms of:

$$\sigma_s^2 = \sigma_v^2 + \sigma^2 \dots\dots\dots (5)$$

and

$$\gamma = \sigma^2 / \sigma_s^2 \dots\dots\dots (6)$$

Where γ- parameter has a value between zero and one.

### 3.3 Empirical frontier model for rice-based fadama farmers in Adamawa state

The estimated Cobb-Douglas stochastic frontier production function is assumed to specify the technology of the farmers. It is specified as:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + \beta_6 \ln X_{6ij} + \beta_7 \ln X_{7ij} + \beta_8 \ln X_{8ij} + V_{ij} - \mu_{ij} \dots\dots\dots (7)$$

Where ln represents logarithm to base e; subscripts ij refers to the jth observation of the ith farmer; Y is the value of total output of the farmers in Naira; X<sub>1</sub> represents the total land area under cultivation (in hectares); X<sub>2</sub> is the amount spent on inorganic fertilizer (in naira); X<sub>3</sub> represents family labour (in standard days); X<sub>4</sub> is hired labour (in naira); X<sub>5</sub> is the amount spent on seeds (in naira); X<sub>6</sub> represents the amount spent on agro-chemicals (in naira); X<sub>7</sub> is water and irrigation charges (in naira); and X<sub>8</sub> represents other costs which include transportation, empty sacks and rent on land (in naira).

It is assumed that the technical inefficiency effects are independently distributed and μ<sub>ij</sub> arises by truncation (at zero) of the normal distribution with mean μ<sub>ij</sub> and variance, δ<sup>2</sup>, where μ<sub>ij</sub> is defined as:

$$\mu_{ij} = \delta_0 + \delta_1 \ln Z_{1ij} + \delta_2 \ln Z_{2ij} + \delta_3 \ln Z_{3ij} + \delta_4 \ln Z_{4ij} \dots\dots\dots (8)$$

Where  $\mu_{ij}$  represents the technical efficiency of the  $i^{\text{th}}$  farmer;  $Z_1$  denotes years of farming experience;  $Z_2$  is the number of years of formal education;  $Z_3$  denotes number of meetings with extension agents; and  $Z_4$  is the household size.

The maximum – likelihood estimates of the  $\beta$  and  $\delta$  coefficients in equations (7) and (8) respectively was estimated simultaneously using the computer program FRONTIER 4.1 (Coelli, 1994).

#### 4. Results and Discussions

Three crop mix pattern were identified, namely, Rice mono-cropping, Rice-maize and Rice-cocoyam (Table 2). Dry season rice-based farming in the State is usually undertaken on a small land area due largely to the farmers being small-scale and increasing scarcity of *fadama* farmlands owing to growing competition between cultivators and pastoralists (Fatola, 1988).

**Table 2:** Distribution of farmers according to cropping patterns and areas cultivated

<b>Cropping Pattern</b>	<b>Frequency</b>	<b>Area Cultivated (ha)</b>	<b>%Area Cultivated</b>
Rice Mono-cropping	95	34.84	84.50
Rice-Maize	22	5.76	13.97
Rice-Cocoyam	05	0.63	1.53
<b>Total</b>	<b>122</b>	<b>40.64</b>	<b>100.0</b>

**Source:** Field survey data, 2003.

The distribution of farmers according to cropping patterns and cultivated land area shows that approximately 85% of the farmers were involved in rice mono-cropping, which is the common practice in the study area. On the contrary, only 15% of the sample farmers grew rice in mixtures with either cocoyam or maize.

The consideration for risk minimisation may be major factor accounting for the practice of mixed-cropping (Norman, 1974; Just and Candler, 1985). A study by Abalu (1976) on crop mixtures in Northern Nigeria contends that crop mixtures are employed by farmers primarily as risk-minimising precautions and that the immediate objective of farmers is not only one of profit maximisation but also of stability of income.

Table 3 shows the summarized results of the maximum likelihood estimates of Cobb-Douglas stochastic frontier production function for rice-based *fadama* farmers in the State. The result shows that land, seeds and other costs were significant at 1% level; while fertilizer and water were significant at 5% level.

**Table 3:** Maximum likelihood estimates of Cobb-Douglas stochastic frontier model for rice-based farmers

Variables	Parameters	Coefficients	t-ratio
<i>Production factors</i>			
Intercept	$\beta_0$	2.646	5.007***
In (Land)	$\beta_1$	0.157	3.794***
In (Fertilizer)	$\beta_2$	0.172	1.969**
In (Family Labour)	$\beta_3$	0.062	1.702*
In (Hired Labour)	$\beta_4$	-0.004	-0.786
In (Seeds)	$\beta_5$	0.146	3.208***
In (Agro-Chemicals)	$\beta_6$	0.007	1.351
In (Water + Irrigation Charges)	$\beta_7$	0.081	2.014**
In (Other Cost)	$\beta_8$	0.382	7.038***
<i>Inefficiency Model</i>			
Intercept	$\delta_0$	0.0345	0.026
Farming experience	$\delta_1$	-0.068	-3.521***
Level of Education	$\delta_2$	-0.866	-4.828***
Extension Contact	$\delta_3$	0.673	0.293
Household size	$\delta_4$	-1.429	-0.363
Number of observations	122		

\*\*\*, Significant at the 0.001 level; \*\*, at the 0.05 level; \*, at the 0.10 level

**Source:** Summarized from computer output

The estimated coefficients for land, fertilizer, family labour, seeds, water and other costs were all positive, which conform to *a priori* expectation, and significant. The positive coefficients of these variable inputs imply that increase in quantities of these inputs would result in increase output.

The sources of inefficiency are examined by using the estimated  $\delta$ -coefficients in Table 3 associated with the inefficiency variables in equation 8. The inefficiency factors are specified as those relating to farmers' specific socio-economic characteristics. These include the farmer's years of farming experience, educational levels, extension contact and household size.

The result of the inefficiency model shows that all the coefficients of the efficiency variables with the exception of extension contact have the expected signs. Since the dependent variable of the inefficiency function represents the mode of inefficiency, a negative sign on an estimated parameter implies that the associated variable has a positive effect on efficiency, and a positive sign indicates that the reverse is true. Hence, level of education, years of farming experience and household size have positive influence on the efficiency of the *fadama* farmers in Adamawa State. However, years of farming experience and level of education were found to have significant effect on technical efficiency of the farmers at 1% level.

The coefficient of farming experience is estimated to be negative as expected and statistically significant at the 1-percent level. The implication is that farmers with more years of farming experience tend to be more efficient in rice production. This conforms with the findings of Coelli and Battese (1996) who reported a negative production elasticity with respect to farming experience for farmers in two villages in India, thus suggesting that older farmers are relatively more efficient, and vice versa. It is possible that such farmers gained more years of farming experience through "learning by doing," and thereby becoming more efficient.

The coefficient of education variable is estimated to be negative as expected and statistically significant at the 1-percent level. The implication is that farmers with more years of formal schooling tend to be more efficient in rice production, presumably due to their enhanced ability to acquire technical knowledge, which makes them move close to the frontier output. This

finding agrees with comparable findings by Battese *et al* (1996), Coelli and Battese (1996) and Seyoum *et al* (1998). It is very plausible that the farmers with education respond readily to the use of improved technology, such as the application of fertilizers, use of pesticides and so on, thus producing closer to the frontier.

Table 4 shows the technical efficiency ratings of the farmers. It reveals that predicted technical efficiencies differ substantially ranging between 0.26 for the least practice farmer and 0.97 for the 'best' practice farmer, with a mean technical efficiency of 0.80. The wide efficiency differentials among these farmers are an indication of a substantial potential for efficiency improvement in rice-based production. This result indicates that, on the average, output of rice-based production fall by 20% from the maximum possible level, and 17% from the best practice farmer. Approximately 65% of the farmers have technical efficiency of 80% and above, which is attributed to full utilization of existing *fadama* resources (Abdullahi and Philip, 1990) owing to their relative small sizes, making them easier and cheaper to manage.

**Table 4:** Distribution of Technical Efficiency ratings of Rice-based *Fadama* Farmers in Adamawa State

<b>Efficiency Index</b>	<b>Number of Farms</b>	<b>Percentage of Farms</b>
<0.40	2	1.64
0.40 – 0.49	5	4.09
0.50 – 0.59	13	10.66
0.60 – 0.69	7	5.74
0.70 – 0.79	16	13.11
0.80 – 0.89	40	32.79
0.90 – 1.0	39	31.97
<b>Total</b>	<b>122</b>	<b>100.0</b>
Mean Efficiency	0.80	
Minimum Efficiency	0.26	
Maximum Efficiency	0.97	

**Source:** Computed from MLE results

## 5. Conclusion and Recommendations

The conclusion drawn from the study is that there were wide efficiency differentials among farmers in the study area and that rice-based crop production could be increased by 20 percent through better use of available resources, given the current state of technology.

Farmer-specific factors such as education and farming experience were found to contribute positively and significantly to farmers' efficiency levels in rice-based production. The implication of this study is that, technical efficiency of the farmers can be increased by 20% through intensive use of available resources, especially land, fertilizer, water and seeds given the current state of technology.

Given the significance of the fertilizer input, it is important to design policies to ensure that farmers have good access to fertilizers through adequate supply, and efficient distribution. This could be achieved through the expansion of domestic production and the development of rural infrastructure, especially rural roads that can facilitate accessibility at lower cost to the farmer.

Also, there should be policy intervention that facilitates farmers' access to improved rice seeds to enhance efficiency and competitiveness in production. Closely associated with this policy, the provision of adequately trained and equipped extension workers for disseminating extension messages, has the potential of raising efficiency.

With regards to farmer-specific factors, especially education, there is the need for policy to promote formal education as a means of enhancing efficiency in production over the long-term period. As this would enable farmers make better technical decision and also help in allocating

their production inputs effectively. In the short-term, informal extension education could be effective, especially when targeted at farmers who have had limited formal educational opportunities.

## References

- Abalu, G.O.I (1976) "A Note on Crop Mixtures under Indigenous Conditions in Northern Nigeria" *Journal of Development Studies* Volume 12, No.3pp 212-220.
- Aigner, D.C., Knox, L. and Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier production function models. *Journal of Econometrics*, No. 6, pp. 21 – 37.
- Abdullahi, A. and Philip, D.O. (1990). "The Role of Irrigation in Rural Development in Nigeria", Proceedings of the National Workshop on *Fadama* and Irrigation Development. Oct. 23<sup>rd</sup> – 25<sup>th</sup>, 1989, Bauchi, Nigeria.
- Adamawa, ADP (1996). Crop Production Recommendations for Adamawa State, P. 4.
- Amaza, P.S. and Olayemi, J.K. (2002). Analysis of Technical Inefficiency in Food Crops Production in Gombe State, Nigeria. *Applied Economics Letters*, 9, pp.51-54.
- 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, pp325-332.
- Battese, G. E., Malik, S. J.Gill, M. A. (1996) 'An Investigation of technical inefficiencies of production of wheat farmers in four districts of Pakistan. *Journal of Agricultural Economics*, 47, pp37-49.
- Coelli, T.J. (1994). A guide to FRONTIER 4.1: A computer program for stochastic Frontier production and cost function estimation. Department of Economics, University of New England, Armidale, Australia.
- Coelli, T.J. and Battese, G. (1996). Identification of factors which influence the technical Inefficiency of Indian farmers, *American Journal of Agricultural Economics*, No. 40, pp. 103 – 128.
- Farrell, M.J. (1957). The measurement of productive efficiency, *Journal of the Royal Statistical Society*, No. 120, pp. 253 – 281.
- Fatola, J.A. (1988). "Land and Water Rights in Kisingin Rehabilitated *Fadama*: Crisis and Resolution", *Development and the Nigerian Environment: Abstract of Proceeding*. 31NGA Conference, Port- Harcourt, pp 12 – 16.
- FAO (2003) FAO Production year book, Rome.
- FAO (2003) FAO Trade year book, Rome.
- Federal Ministry of Agriculture, FMA(1995). Planning, Research and Statistical Data IITA (1994). IITA Annual Report, IITA Ibadan, Nigeria, 14pp.

- Just, Richard E. and Candler, Wilfred (1985) "Production Functions and Rationality of Mixed Cropping" *European Review of Agricultural Economics*, vol.12, No.3, pp 207-231.
- Helfand, S.M. (2003). Farm size and determinants of productive efficiency in the Brazilian centre west. Proceeding of the 25<sup>th</sup> International Conference of Agricultural Economics, Durban, South Africa, 16<sup>th</sup> – 22<sup>nd</sup> August. Pp605-612.
- Maurice, D.C. (2004). "Resource productivity in cereal crops production among *fadama* framers in Adamawa State, Nigeria". *M.Sc. Thesis*, Department of Agricultural Economics and Extension, University of Maiduguri.
- Norman, D.W (1974) "Rationalizing Mixed Cropping Under Ingenious Conditions: The Example of Northern Nigeria, *Journal of Development Studies*, Vol. 11. No.1, pp3-21.
- Meeusen, W. and Van den Broeck (1977). Efficiency estimates from Cobb-Douglas production function with composed error, *International Economic Review*, No.18, pp 435 – 444.
- Seyoum, E. T., G. E. Battese and E.M Fleming (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*, 19, pp341-348.
- Onyenweaku, C.E., Agu, S.E. and Obasi, F.C. (2000). Economics of small holder rice farming under different production systems in south-eastern Nigeria, *Journal of Agric Business and Rural Development*, Vol. 1, No. 1, pp 1 – 9.
- World Bank (1991). Staff Appraisal: Report on National *Fadama* Development Federal Republic of Nigeria Agricultural Operations, Division I, Washington, D.C.