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**DETERMINANTS OF TECHNICAL EFFICIENCY AND VARIETAL-GAP OF
RICE PRODUCTION IN NIGERIA: A META-FRONTIER MODEL APPROACH**

BY

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ABSTRACT

This study uses the concept of meta-frontier function to examine the technical efficiency and varietal-gap of rice production in Nigeria. A random sample of 675 farmers was selected from three out of six geographical zones in Nigeria. The farmers in this study were classified into three groups according to the variety of rice they planted. The three main varieties of rice planted are local (Ofada), improved (Mai-Nasara) and New Rice for Africa (NERICA). The technical efficiency indices were computed using the meta-frontier approach because production varieties and technologies were expected to differ between the three varieties. This method allows the measure of the varietal-differences which is the Technology Gap Ratio (TGR). Estimates of the frontier were obtained assuming a translog functional form. Results revealed mean technical efficiency of 55%, 58% and 57% for Ofada, Mai-Nasara and NERICA varieties, respectively. Farm size, hired labour, fertilizer, seed, age, gender, household size and amount of credit are the determinants of technical efficiency of farmers in Nigeria rice production. The average values of varietal technology gap are more than 0.83 in all the varieties. This suggests high differences between the varieties and a need for application of frontiers that accommodate such differences. To increase efficiency in rice production in Nigeria, farm size, fertilizer usage, seed quantity and credit need to be increased.

INTRODUCTION

Nigeria is blessed with various climatic zones, enormous resources and the potentials needed for producing, processing, marketing and exporting of different agricultural produce (Babafada 2003). Agriculture is an indispensable sector in Nigerian economy because it remains the only local source of food and natural fiber for man (Adubi 2002), In spite of the dominance of petroleum, agriculture still plays vital roles in Nigerians economy. The sector contributes to the country's gross domestic product (PCU, 2002); provides up to about 70% of the active labour force (Olatunji 2002; Bello 2004a; Ayinde 2008), supplies raw materials required by the industrial sector and generates foreign exchange through export (CPU 2002). In spite of this, agricultural production has failed to meet the food needs of the country's rapid growing population. This has led to constant

food shortages rising farm product prices and huge importation of food by the government. The poor performance of Nigerian agriculture is a result of the system of production characterized by small uneconomic production units, fragmentation of land holdings and predominance of poor management of production techniques (Onyenweaku and Nwaru 2005)

Rice is important crop world wide. Babafada (2003) asserted that rice is the fourth major cereal in Nigeria after maize, sorghum and millet. Globally, rice production has been increasing since the 1960s. From 1965 – 1979, the areas cultivated to rice increased from 124 million hectares to 145 million hectares while the output rose from 253 million tonnes to 380 million tonnes. This performance was attributed to the Green Revolution in Asia, Europe and Latin America through the adoption of modern cultivars, which is, the high yielding varieties (HYV). These high yielding varieties were adopted in Sub Saharan Africa, Nigeria inclusive.

Nigeria has a leading role in rice production in West Africa. Rice is grown virtually in all the agro-ecologies of Nigeria with over 4.0 million hectares of land suitable for rice cultivation, but only about 2.0 million hectares is currently being cultivated with over 3.8 tones of rice crop per annum (Abubakar 2003). Considering its vast agricultural land and suitable ecology, Nigeria is endowed to produce enough rice to satisfy domestic demand and has the potential to export to other countries (Babafada, 2003). The Country is both the highest producer and consumer of rice in the Sub-region with figures slightly above 50% (WARDA, 1996). The increase in rice consumption in Nigeria is attributed to rapid population growth, urban residents' exposure to dietary patterns of foreign cultures, urban lifestyles with preference for foods which require less time to prepare and rising

household income (Ojehomon et.al 2004). National rice production between 2002 and 2004 was 3.065 million metric tons while demand was about 5.0 million metric tonnes.

In spite of the increase in production of about 1.8 percent, the demand for rice outstripped supply (Adeoye 2003; Ojehomon et.al. 2004; Bello 2004a) consequently the country has been importing to bridge the supply-demand gap (Bello 2004b). Rice importation rose from 1,100 metric tonnes in 1961 to 594,057 metric tons in 1995. It was at 687,925 metric tonnes in 1999 representing an estimated \$259million in scarce foreign exchange for that year. This rose to \$655 million and \$756 million in 2002, and 2003 respectively, Nigeria alone accounted for 3 percent of the value of rice imported into West Africa (Adeoye, 2003). This constitutes a huge drain on Nigeria foreign reserve and a major bottleneck in the balance of payments (Egbuna, 2003). Nigeria has become a major rice importer in the world and only second to Indonesia. Increasing domestic rice production to satisfy the growing rice consumption and reduce rice import has become a top priority to the Nigeria Government and a great concern in the global world. This study therefore, examines the determinants of technical efficiency of rice production in Nigeria.

The efficiency with which farmers use resources and improved technologies available to them are important in Nigeria agricultural production since major problem in the Country still revolves around low productivity (Rahji 2005). The implication is that there is scope for additional increase in output from existing hectares of food crop if resources are properly harnessed and efficiency allocated (Rahji 2005).

Earlier production and efficiency studies on rice production in Nigeria focuses on estimation of technical efficiency assumed homogenous technology across farms (Abdurahaman et. al. 1998, Nnana 2006, Rahji and Omotesho 2006, Okoruwa and

Ogundele, 2006). However this study focuses on the estimation of rice production efficiency with a more flexible functional form, a large data set and using a method that recognizes the possibility of heterogeneity in production technology,

The study using meta-frontier approach examines the technical efficiency of rice production; compares the technical efficiency estimates of rice production of meta-frontier with the standard stochastic frontier approaches; estimates the varietal - technology differences and identifies the determinants of technical efficiency of rice production in Nigeria.

METHODOLOGY

The study was conducted in Nigeria. Nigeria is situated in the West African region and its main longitudes and latitudes is 10°N and 8°E respectively (Mapsofworld 2009). It has a land mass of 923,768 square kilometer that falls within its latitude and longitude with a broad longitudinal range of diverse ecological lands in the south to the interior uplands, plateau and highlands in the North. Nigeria has a total population of about 140million (Census, 2006). Rice production is the focus of this study. The three rice varieties predominantly grown in Nigeria are the local variety commonly called *Ofada*, the improved variety which is commonly called *Mai-Nasara* and the New Rice for Africa (*Nerica*) known as Africa miracle.

The study used both primary and secondary data, the primary data involved the use of well structured questionnaire while secondary data were obtained from journals and other relevant publications. Primary data were obtained from the rice producing farmers in the

study area. Primary data were collected on socio-economic characteristics of the farmers such as age, farming experience, household size, land ownership system, sources of labour and credit. Production-marketing information such as varieties of rice planted, quantity of the used inputs, farm size, amount of man-days; amount of credit; output and yield in rice production, source of seeds, fertilizer, herbicides, prices of inputs and output.

Sampling Procedure

A multi-stage sampling technique was used for selecting representative rice producing farmers in Nigeria. The first stage was the random selection of three out of the six geopolitical zones in the Country. The three randomly selected zones are south-south, south-west and north central. The second stage was the selection of the state with the highest rice production in each of the zones. The third stage involved random selection of three (3) rural communities in each state. The last stage involved the random selection of twenty-five rice farmers in each of the rural communities. Seventy-five rice farmers were therefore selected from each zone, making a total of six hundred and seventy five respondents in the country.

METHOD OF ANALYSIS

ANALYTICAL FRAMEWORK

The earliest of the efficiency theories is the production theory and the concept of isoquants which centers on the relationships between input and output.

The isoquants represent the boundaries of inputs sets while the production on possibility curves (frontiers) are the boundary of the outputs sets. The output and input function are often used to characterize the production function. This serves as basis for technical efficiency measurement. The production function which has been extended over the years to accommodate different circumstances (Aigner, Lovell and Schmidt, 1977, and Meeusen and van den Broeck, 1977, Pitt and Lee, 1981, Jondrow et al., 1982, Battese and Coelli, 1992 and Kumbhakar, 2002).

One of the most recent extensions of the model is meta-frontier model. The meta-frontier production model has the advantage of enveloping the stochastic frontiers of different groups like farms, variety, Regions or even Countries. It can be defined by all the different groups in a way that is consistent with the specification of a stochastic frontier model (Battese and Rao (2002) and Battese, Rao and O'Donnell (2004). The model estimates of technical inefficiencies can accommodate the heterogeneity in technologies across firms in the industry. This stochastic meta-frontier framework proposed by Battese and Rao (2002) and further developed by Battese, Rao, O'Donnell, and Battese (2004) not only allows an examination of the technical inefficiencies of firms but also provides a measure of the technology gap. The meta-frontier technique entails the estimation of a metatechnology and the frontiers of relatively homogenous groups. The estimation of a meta-frontier, group frontiers, and the relative efficiency levels with respect to both, allows the construction of a measure of the *technology gap* between farms of different varieties with efficiency effects removed to give a clearer picture of the relative rates of technology differences between production entities. O'Donnell, et al, (2005), O'Donnell,

et al (2007) Boshrabadi et al, (2007) and Rambaldi et al have also given various applications to this approach.

The meta-frontier production function model is given by

$$Y_{it}^* \equiv f(x_{it}, \beta^*) = e^{x_{it}\beta^*}, i = 1, 2, \dots, L = \sum_{k=1}^K L_k; t = 1, 2, \dots, T, \text{-----}(1)$$

where Y_{it}^* is the meta-frontier output that dominates all group frontiers; x_{it} denotes a vector of values of functions of inputs used by the i-th unit in the t-th period; K is the different variety, L_k is sample data units for k-th variety, T is the period of time and β^* denotes the vector of parameters for the meta-frontier function such that

$$x_{it}\beta^* \geq x_{it}\beta_{(K)} \text{-----}(2)$$

Where $\beta_{(K)}$ denotes the vector of parameters for the k-th variety.

The meta-frontier function, defined by equations (1) and (2), is a production function of specified functional form that does not fall below the deterministic functions for the stochastic frontier models of the regions involved. Battese and Rao (2002) give a more extensive literature review and proposed a stochastic meta-frontier model that assumes a different data-generation mechanism for the meta-frontier than for the different regional frontiers. The meta-frontier is assumed to be a smooth function and not a segmented envelope of the stochastic frontier functions for the different regions. The meta-frontier function of equation (1) can be alternatively expressed in terms of the output y as

$$Y_{it} = e^{-U_{it(k)}} \times \frac{e^{x_{it}\beta_{(k)}}}{e^{x_{it}\beta^*}} \times e^{x_{it}\beta^* + V_{it(k)}} \text{-----}(3)$$

Where Y_{it} denotes the output for the i -th unit in the t -th period for k -th variety and $e^{-U_{it(k)}}$ which is the first term on the right-hand side of equation (3) is the technical efficiency (TE) relative to the stochastic frontier for the k -th variety,

$$TE_{it}^k = \frac{Y_{it}}{e^{x_{it}B_{(k)} + V_{it(k)}}} = e^{-U_{it(k)}} \text{-----}(4)$$

The second term on the right-hand side of equation (3) is the technology gap ratio (TGR) for the i -th unit (in the k -th variety) at the t -th time period:

$$TGR_{it}^k = \frac{e^{x_{it}\hat{\beta}_{(k)}}}{e^{x_{it}\beta^*}} \text{-----}(5)$$

This measures the ratio of the output for the frontier production function for the k -th variety relative to the potential output that is defined by the meta-frontier function, given the observed inputs. The technology gap ratio has values between zero and one because of equation (2).

The *technical efficiency of the i -th unit*, given the t -th observation, *relative to the metafrontier*, denoted by TE_{it}^* is defined in an analogous way to equation (4). It is the ratio of the observed output relative to the last term on the right-hand side of equation (3), which is the meta-frontier output, adjusted for the corresponding random error, i.e.,

$$TE_{it}^* = \frac{Y_{it}}{e^{x_{it}B^* + V_{it(k)}}} \text{-----}(6)$$

Equations (8) - (11) imply that an alternative expression for the technical efficiency relative to the metafrontier is given by

$$TE_{it}^* = TE_{it}^k + TGR_{it}^k \text{-----}(7)$$

Thus the technical efficiency relative to the metafrontier function is the product of the technical efficiency relative to the stochastic frontier for the given region and the technology gap ratio for that region. Because both the latter measures are between zero and one, the technical efficiency relative to the metafrontier is also between zero and one, but is less than the technical efficiency relative to the stochastic frontier for the region of the unit.

Estimates for the technical efficiencies of units relative to the metafrontier function can be predicted by

$$T\hat{E}_{it}^* = T\hat{E}_{it}^k + TGR_{it}^k \text{-----}(8)$$

Where $T\hat{E}_{it}^*$ is the predictor for the technical efficiency relative to the k-th regional frontier, as proposed in Battese and Coelli 1992, which is programmed to be calculated in FRONTIER; and $TGR_{it}^k = \frac{e^{x_{it}\hat{\beta}_{(k)}}}{e^{x_{it}\hat{\beta}^*}}$ is the estimate for the technology gap ratio for the i-th unit in the k-th region relative to the industry potential, obtained by using the estimates for the parameters involved. Standard errors for the estimators for the meta-frontier parameters can be obtained using simulation or bootstrapping methods.

Varietal-Technology Gap Ratio (VTGR)

The notion of a Technology Gap Ratio (TGR), defined in equation (5), is that of a gap between the production frontier for a particular group in an industry and the meta-frontier for the industry. It is helpful to expand this definition to the variety-technology gap ratio (VTGR). This specific definition suits our purpose in this study in that it describes the

constraints placed on the potential output by rice variety production, and the interactions between production technology and that variety (Boshrabadi *et al*, 2007). It is importance for researchers of rice production to realize the fact that the VTGR enables us to assess the potential of the production system according to variety. Characteristics of the three rice varieties that are the focus of this study differ significantly. In particular, the *ofada* variety is local variety with low output and sensitive to weed, drought and other risk associated with rainfed ecologies. The output of the Mai Nasara variety is of high yield being an improved breed but can only express it full potential under high inputs like pure seed, fertilizers; good technology and management conditions. Finally, the *NERICA* variety an Africa miracle seed is drought tolerant, insensitive to weed, high yielding and well suited to the low-input and poor management condition of rainfed rice farming (Osiname, 2002). Statistics reported above suggest that yield, input use and area planted differ between varieties.

Empirical model and variables

The estimated model used in this study is the model using a translog functional form of equations (1) and (3), specified by:

$$\ln Y_{it(k)} = \beta_{o(k)} + \sum_{j=1}^{12} B_j \ln X_{ij(k)} + 1/2 \sum_{j=1}^{12} \sum_{i=1}^{NK} B_{j(k)} \ln X_{ijt} \ln X_{it(k)} + V_{it}^k - U_{it}^k$$

Where $U_{it}^k = \sum (\exp[-\eta(t-T)]) U_i$ and U_i is defined by the nonnegative truncation of the $N(\mu, \sigma_2)$ -distribution.

Where j represents the j -th input ($j = 1, 2, \dots, 12$) of the i -th firm ($1, 2, \dots, Nk$) in the t -th time period ($t = 1, \dots$) in the k -th varietal group ($k = 1, 2, 3$); $\beta_{ij(k)} = \beta_{ji(k)}$ for all j and k ; Y_i represents the physical output of rice production. This output also includes the portion consumed and given away as gift. The output was measured in kilogram; $X_{i1(k)}$ is the total area planted to rice (in hectares); $X_{i2(k)}$ represents family labour expressed in man days equivalent. Labour input used was standardized into adult male equivalent man days, which is about eight hours per day. The use of family labour is crucial to farm operation in the rural area. Family labour can be in man day, woman day or child day. A woman day is 0.75 man day while a child day is equivalent to 0.50 man day (Olayide and Heady, 1982); $X_{i3(k)}$ represents hired labour in man day; $X_{i4(k)}$ represents the quantity of fertilizer used in Kilogram; $X_{i5(k)}$ is the quantity of herbicide used is in litres; $X_{i6(k)}$ is quantity of seed in kilogram; and $X_{i7(k)}$ is the age of farmers in years; $X_{i8(k)}$ represents education of respondent. This was measured as a dummy variable 1 for formal education and zero for informal education. This is because all the farmers have one form of education or the other; $X_{i9(k)}$ represents gender as a dummy variable where dummy 1 is for male and zero for female; $X_{i10(k)}$ represents family size in number; $X_{i11(k)}$ represents land ownership pattern; $X_{i12(k)}$ represents amount of credit in Naira. $Y_{it(k)}$ and all $X_{it(k)s}$ are mean-corrected to zero in the translog functional form, which implies that the first-order coefficient estimates of the model represent the corresponding elasticities. All these variables are expected to explain the technical efficiency levels in rice production in the study area and were fitted into a multiple regression equation.

RESULT AND DISCUSSION

Stochastic frontier estimates for the individual varieties were estimated using *FRONTIER* 4.1c (Coelli, 1996) while the meta-frontier was estimated using *SHAZAM* following O'Donnell, Rao and Battese (2004). The results are shown in Table 1. The acronyms for the models are defined as follows:

SFA-POOL is the ML estimate of the stochastic frontier for all rice variety data

SFA-VG is the ML estimates of the stochastic frontiers for rice variety group

SFA-MF LP is the LP estimates of the stochastic metafrontier

The results of a likelihood-ratio test using a mixed chi-squared distribution confirms the presence of technical inefficiency for all varieties. We thus conclude that the technical inefficiency term is a significant addition to the individual variety and pooled models. The pooled stochastic frontier was estimated to test for differences in group (variety) frontiers. The generalized likelihood ratio test statistic for the null hypothesis that the group frontiers are the same was rejected. Accordingly, the estimation of the meta-frontier production model is justified.

[Table 1 here]

Estimates of technical efficiencies and VTGRs are presented in Table 1. In the estimated pooled frontier model, mean technical efficiencies are fairly uniform across varieties. The farmers growing the *Mai-Nasarai* variety achieved the highest mean technical efficiency (0.68) with minimum variation. Farms growing the *ofada* variety had the lowest mean technical efficiency (0.64) and highest variation. The mean technical efficiency across all varieties is 0.66. Estimates of mean technical efficiencies differ much more between varieties in the estimated group frontier models. Farms growing the *NERICA* variety

achieved the highest mean technical efficiency (0.68) with minimum variation in the variety group frontier model. However farmers growing *ofada* variety achieved the lowest mean technical efficiency (0.65) and farmers growing the *Mai-Nasara* variety had the highest variation. The mean technical efficiency across all varieties is estimated at 0.66, similar to the estimate for the pooled frontier. However, these results can be misleading in that insufficient allowance is made for differences in production technology arising from the use by farmers of different rice varieties. There is also a shortcoming in the estimation of individual group frontiers in that their efficiency levels cannot be compared; nor can VTGRs be estimated. Both of these problems are overcome by estimating the meta-frontier model where, as expected, technical efficiency estimates are lower but much less dispersed. The meta-frontier model results reveal that the farmers growing the *Ofada* variety achieved mean technical efficiency of 0.55; that of *Mai Nasara* is 0.58 and that of *NERICA* 0.57. The mean technical efficiency values from meta-frontier model have lower variation. This suggests that the meta-frontier had taken care of the differences in the varieties. The farmers growing the *Mai-Nasara* variety has the highest VTGR (0.86). This indicates that the varieties are very different. The VTGR for *NERICA* farms is 0.85 while that of *Ofada* is 0.85. This indicates that choice of variety is playing a major role in preventing individual farmers from operating on or near the meta-frontier. That is not to say that a producer cannot be located on the meta-frontier because of the rice variety that has been planted. The maximum estimated VTGR is unity for all varieties, which means that the three group frontiers are tangent to the meta-frontier. But the producers who planted the *Mai-Nasara* variety are located on or close to the meta-

frontier than producers who planted the other two varieties. The results revealed that generally the Nigeria rice farmers are technically inefficiency.

Insert table 2

The summary statistic on the determinant of technical efficiency is shown in table 2. The results from the rice variety group model differ from the meta-frontier model. The meta-frontier model revealed that farm size (β_1); Hired labour (β_3); fertilizer (β_4); (β_5), seed (β_6); Age (β_7); gender (β_9); household size (β_{10}) and amount of credit (β_{12}) are the significant determinant of rice production efficiency in Nigeria. Only farm size, fertilizer and amount of capital have positive influence on rice production efficiency for the three varieties under consideration. Age and the household size are also commonto all the varieties but have negative influence on efficiency of rice production. Seed is a significant variable in the *Mai-Nasara* variety group but exerts a negative influence on its production efficiency. There may be a need for reduction in rice seed input in *Mai-Nasara* rice production to enhance its technical efficiency.

Bring more farm land under rice cultivation with more fertilizer and more capital outlay has the tendency of increasing the technical efficiency of rice farmers. Reducing the number of household size also has the likely effect of increasing rice farmers' production. The younger farmers have the tendency of being of higher efficiency.

Conclusion and Recommended

The result shows that there are technical inefficiencies among the Nigeria rice farmers. Use of the meta-frontier method enabled technical efficiency scores to be corrected by

the coefficient of the VTGR, which showed that difference exists in technical efficiency between farms growing the different varieties. This indicates high differences among the varieties and a need for application of frontiers that accommodate such differences.

With technical efficiency estimation based on varieties, *NERICA* was proved to be most efficient however, estimation based on technology difference through meta-frontier, *Mai-Nasara* was proved to be most efficient. Local variety (*Ofada*) proved to be the most inefficient. Hence improved varieties have the tendency of enhancing greater efficiency of farmers in Nigeria rice production.

Farm size, hired labour, fertilizer, seed, age, gender, household size and amount of credit are the significant determinants of technical efficiency of farmers in Nigerian rice production. It can be recommended that in order to increase efficiency in rice production the farm size, fertilizer and seed amount credit should be increased. There is also the need for farm families to engage in family planning in order to have smaller household size. Young people need be encouraged to go into rice farming.

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Table1: Technical Efficiency and Technology Gap Ratio Estimates for Different rice varieties

		Mean	SD	Min	Max
LOCAL (<i>Ofada</i>)	SFA POOL	0.6428	0.1564	0.1562	0.9300
	SFA-VG	0.6547	0.1409	0.1605	0.9181
	SFA-MF	0.5488	0.1476	0.1583	0.9240
	VTGR	0.8382	0.0341	0.7715	1.0608
IMPROVED (<i>Mai Nasara</i>)	SFA POOL	0.6796	0.1345	0.1587	0.9334
	SFA-VG	0.6745	0.1486	0.1282	0.9460
	SFA-MF	0.5770	0.1408	0.1434	0.9397
	VTGR	0.8556	0.0329	0.7490	1.1190
NERICA	SFA POOL	0.6662	0.1385	0.1587	0.9131
	SFA-VG	0.6787	0.1370	0.1718	0.920
	SFA-MF	0.5725	0.1374	0.1652	0.9167
	VTGR	0.8435	0.0170	0.7229	1.0500

Table 2: Summary statistics of determinants variable of technical efficiency

Parameter		β_0	β_1	β_3	β_4	β_6	β_7	β_9	β_{10}	β_{12}	γ	σ^2	Log L	LR
Estimations														
<i>Ofada</i> (Local)	Coeff	7.65	0.81	–	0.06	–	-0.02	0.22	0.03	0.35	0.73	0.52	-172.70	0.85
	SD	0.48	0.07	–	0.01	–	0.01	0.08	0.01	0.11				
<i>Mai-Nasara</i> (Improved)	Coeff	7.87	0.76	–	0.06	-0.10	-0.01	–	-0.02	–	0.81	0.42	135.08	0.17
	SD	0.41	0.06	–	0.20	0.06	0.01	–	0.07	–				
<i>Nerica</i>	Coeff	7.27	0.77	0.07	0.07	–	-0.01	0.10	0.05	0.17	0.76	0.42	-144.27	0.12
	SD	0.44	0.06	0.05	0.01	–	0.01	0.07	0.01	0.09				
Pooled Frontier	Coeff	7.56	0.78	0.06	0.07	-0.06	-0.01	0.09	0.03	0.22	0.77	0.47	-470.11	0.38
	SD	0.25	0.03	0.02	0.01	0.03	0.01	0.04	0.01	0.06				
Meta- frontier	Coeff	7.45	0.77	0.06	0.07	-0.05	-0.01	-0.08	0.03	0.24	0.76	0.45	-380.11	0.55
	SD	0.21	0.03	0.02	0.01	0.03	0.01	0.03	0.01	0.06				