TECHNICAL EFFICIENCY DIFFERENTIALS IN RICE PRODUCTION TECHNOLOGIES IN NIGERIA

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Abstract

This paper examined technical efficiency differentials between farmers planting two varieties of rice: traditional and improved varieties in Nigeria. A multistage random sampling procedure employed for the selection of 302 respondents comprising 160 traditional rice varieties and 142 improved rice varieties farmers across four major rice producing states in the country. The study used stochastic frontier production functions in which the technical inefficiency effects are assumed to be functions of education of farmers, number of contact with extension personnel, rice farming experience and household size. Empirical results indicate that significant increase recorded in output of rice in the country could be traced mainly to area expansion. The use of some critical inputs such as fertilizer and herbicides by the farmers were found to be below recommended quantity per hectare. There was also significant difference in the use of such input as labour between the two groups of farmers. The estimated average technical efficiencies for the two groups were correspondingly high ($\geq$0.90) which indicated that there is little opportunity for increased efficiency given the present state of technology. The non- differential in technical efficiency between the two groups therefore, puts to question the much expected impact of the decades of rice development programmes in Nigeria. The need to develop some low cost labour saving technologies to ease labour constraints on farms was advocated.

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Introduction

Rice is perhaps the world's most important food crop being the staple food of over 50 per cent of the world population, particularly of Indian, China and a number of other countries in Africa and Asia. Rice is one of the major cereals, which have assumed cash crop status in Nigeria, especially in the producing areas, where it provides employment for more than 80% of the inhabitants as a result of the activities that take place along the distribution chains from cultivation to consumption. Due to its increasing contribution to per capita calorie consumption of Nigerians, the demand for rice has been increasing at a much faster rate than domestic production and more than in any other African countries since mid 1970 (FAO, 2001). For example, during the 1960's, Nigeria had the lowest per capita annual consumption of rice in the sub-region with an annual average of 3kg (Table 1). Since then, Nigerian per capita consumption levels have grown significantly at 7.3% per annum. Consequently, per capita consumption during the 1980s average 18kg and reached 22kg in 1995-2000. In a bid to address the demand supply gap, governments, at various times have come up with policies and programmes. But the policies and programme were observed not to have been consistent. These erratic policies reflect the dilemma of securing cheap rice for consumers and a fair price for the producers. Notwithstanding the various policy measures, domestic rice production has not increased sufficiently to meet the increased demand. Thus, these fluctuations in policy and limited capacity of the Nigerian rice sector to match the domestic demand have led the country to expending huge amount of foreign exchange on the importation of rice into the country.

The limited capacity of the Nigerian rice sector to meet the domestic demand has raised a number of pertinent questions both in policy circle and among researchers. For example, what are the factors explaining why domestic rice production lag behind the demand for the commodity in Nigeria? Central to this explanation is the issue of efficiency of the rice farmers in the use of resources. Average yield of upland and lowland rain fed rice in Nigeria is 1.8 ton/ha, while that of irrigation system is 3.0ton/ha (PCU, 2002). This is very low when compared with 3.0 ton/ha from upland and lowland system and 7.0 ton/ha from irrigation system in places like Cote d'Ivoire and Senegal (WARDA and NISER, 2001). Therefore, it appears that rice farmers in Nigeria are not getting maximum return from the resources committed to the enterprise.

Table 1: Comparison between Nigeria and the rest of West Africa

Indicator	Mean (1961-75)	Mean (1976-82)	Mean (1983-85)	Mean (95-2000)
Nigeria				
Production	332800	806222	2306794	3189833
Import	2036	420756	334974	525307
Self-reliance ratio	99%	54%	77%	79%
Total consumption	178199	833640	1599609	2248113
Per capita consumption	3.0	12.0	18	22
West Africa without Nigeria				
Production	1779376	2344073	2822635	4041384
Import	416183	894073	1760884	2107146
Self-reliance ratio	65%	56%	42%	50%
Total Consumption	1178753	1950821	2973885	3985721
Per capital consumption	21.0	27.0	30.0	34

Source: Computed from FAO - AGROSTAT

At present there is no comprehensive and up to date information as regards the level of resource use efficiencies of the farmers. The few available ones were either system based or location specific. Also most of these studies focused mainly on the profitability of the enterprise without in depth enquiry into efficiencies of farmers and factors that determine their levels of efficiency. Thus the main focus of this study is to determine the levels of technical efficiency of these farmers and explain those factors that determine their levels of efficiency. Given the fact that a number of rice development programmes such as varietals improvement, seed development, multiplications and distribution have been implemented to boost the rice sector in Nigeria, the study has been designed to cover farmers planting the improved rice varieties as well as those planting the traditional varieties.

Specifically, the objectives of the study were:

- i to analyze input use and socio-economic characteristics of the farmers;
- ii to determine the technical efficiency of the rice farmers and establish the differentials in technical efficiency between the two groups of farmers;
- iii. to examine factors that determines the level of technical efficiency of the farmers.

2. Conceptual Framework and Review of Literature

The level of technical efficiency of a particular farmer is characterized by the relationship between observed production and some ideal or potential production (Greene, 1993). The measurement of firm specific technical efficiency is based upon deviations of observed output from the best production or efficient production frontier. If a farmer's actual production point lies on the frontier it is perfectly efficient. If it lies below the frontier then it is technically inefficient, with the ratio of the actual to the potential production defining the level of efficiency of the individual farmer. For example, fig 1 shows the comparison of output O_o/O_b at points C_o and C_b, each with the same level of input. But while C_b lies on the best-practices frontier function Q_b (passing through a 100 %-efficient sample point), C_o lies on Q_o which represent a locus that is a neutral shift of the frontier Q_b. The concept could be measured relative to other frontiers, for instance the absolute frontier function Q_a lying above all sample points. In this instance, the ratio will be O_o/O_a or a comparison of output at points C_a and C_o. The potential absolute frontier is also represented by Q_p. This is the maximum output obtained from all conceivable observations embodying the current technology (including over all time periods in which adoption takes place), and it lies above Q_a . Over time, there would be a sequence of absolute frontier functions Q_a's(and associated levels of technical efficiency) moving up to the potential absolute frontier function Q_p.

Farrel (1957) definition of technical efficiency led to the development of methods for estimating the relative technical efficiency of farmers. The common feature of these estimation techniques is that information is extracted from extreme observations from a body of data to determine the best practice production frontier (Lewin and Lovell, 1990). From this the relative measure of technical efficiency for the individual farmer can be derived. Despite this similarity the approaches for estimating technical efficiency can be generally categorized under the distinctly opposing techniques of parametric and non-parametric methods (Seiford and Thrall, 1990).

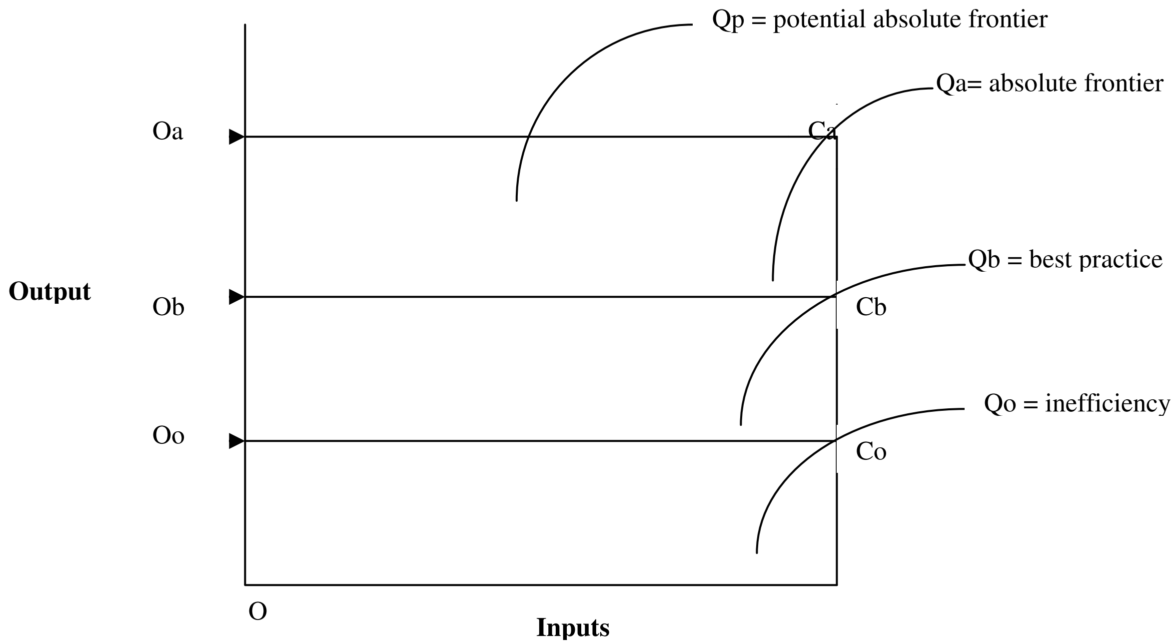


Fig 1: Best practices, potential absolute frontier and measure of inefficiency

Several approaches are used to analyze the determinants of technical efficiency from stochastic production frontier functions. The first followed two- step procedure in which the frontier production function is first estimated to determine technical efficiency indicators while the indicators thus obtained are regressed against a set of explanatory variables which are usually firms' specific characteristics (Greene, 1993; Parikh et al., 1995; Ben-Belhassen, 2000 and Ogundele, 2003). The major drawback in this approach is the fact that it violated the assumption of the error term. In the stochastic frontier model, the error term (the inefficiency effects) are assumed to be identically independently distributed (Jondrow et al, 1982). In the second step however, the technical efficiency indicators obtained are assumed to depend on certain number of factors specific to the firm, which implies that the inefficiency effects are not identically distributed. This major drawback led to the development of more consistent approach which modeled inefficiency effects as an explicit function of certain factors specific to the firm, and all the parameters are estimated in one step using maximum likelihood procedure (Kumbhakar, et al (1991); Reifschneider and Stevenson (1999), Huang and Liu (1994), Battese and Coelli (1995), Ajibefun, et al (1996), Coelli and Battese (1996), Battese and Sarfaz (1998), Seyoum et al (1998), Lyubov and Jensen (1998), Ajibefun and Abdukadri (1999), Obwona (2000), Ajibefun and Daramola (2003).

3. Methodology

3.1 Sample data and variables

Data used for the study were obtained from cross-sectional survey of rice farmers in the four rice producing states (Kaduna , Niger, Ebonyi and Ekiti) that jointly accounted for about 70% of the total rice produced in Nigeria between 2000 and 2003 (PCU, 2003). These four states covered the two major rice production ecologies (upland and the lowland, all rainfed) in the country. A multi stage random sampling technique was adopted in selecting a total of 302 farmers (160 for traditional and 142 for improved technology). Information obtained with of well structured interview schedule include resource inputs and output in rice production; cultural practices of the farmers and their socioeconomic characteristics like age, education, household size etc. A summary of the variables which were used in the analysis is presented in Table 2.

3.2 Empirical Model

Data were analyzed using the stochastic frontier model (Khumbhakar and Hesmatic, 1995; Yao and Liu,1998; Ogundele, 2003). The stochastic production frontier as an econometric method of efficiency measurement in production systems is built round the premise that a production system is bounded by a set of smooth and continuously differentiable concave production transformation functions for which the frontier offers the limit to the range of all production possibilities (Sharma *et al* 1999). It has the advantage of allowing simultaneous estimation of individual technical efficiency of the respondent farmers as well as determinants of technical efficency (Battese and Coelli, 1995). Following Zaibet and Dharmapala 1999, the multiplicative stochastic production function is of the form:

$$Q_i = f(X_{ki}, \beta)e^{\varepsilon i}, \quad i = 1, \ldots ; \ k = 1, \ldots, k \qquad (1)$$

where Q_i is the output of the i^{th} farm, X_{ki}, is a vector of k inputs used by the ith farm, β is a vector of parameter to be estimated and ε_i is the farm specific composite residual term comprising of a random error term v_i and an inefficiency component u_i.

$$\varepsilon_i = v_i + u_i. \quad i = 1, \ldots, n \qquad (2)$$

The two components v and u are assumed to be independent of each other, where v is the two-sided, normally distributed random error ($v_i \sim N(0, \sigma_v^2$), and u is one-sided efficiency component with a half-normal distribution ($u_i \sim N(0, \sigma_u^2 |)$) (Dawson 1990, Sharma *et al* 1999). It follows that the maximum likelihood estimation of Eq. (1) yields estimates for β and λ, where β was defined earlier, $\lambda = \sigma_u / \sigma_v$, and $\sigma^2 = \sigma_v^2 + \sigma_u^2$. Battese and Corra (1977) defined $\gamma = \sigma_u^2 / \sigma^2$, so that $0 \leq \gamma \geq 1$ and represents the total variation in output from the frontier attributable to technical efficiency. Jondrow *et al (*1982) quoted in (Dawson and Lingered 1989; Bravo-Ureta and Rieger, 1991; Zaibet and Dharmapala, 1999) have demonstrated that the farm specific measure of technical inefficiency can be determined from the conditional expectation of ui given εi as:

$$E[u_i | \varepsilon_i] = \frac{\sigma_u \sigma_v}{\sigma} \left[\frac{f^*(\lambda \varepsilon_i / \sigma)}{1 - F^*(\lambda \varepsilon_i / \sigma)} - \frac{\varepsilon_i \lambda}{\sigma} \right] \quad i = 1, \ldots .n \qquad (3)$$

where f* and F* are the values of the standard normal density and distribution functions respectively, evaluated at $\varepsilon_{i\lambda /} \sigma$. The individual farmer's level of technical efficiency (TE_i) is then calculated as:

$$TE_i = \exp(-E[u_i | \varepsilon_i]) \quad i = 1, \ldots\ldots, n \qquad (4)$$

Such that $0 \leq TE_i \leq 1$.

The empirical model of the stochastic production frontier is specified as:

$$\ln Y_{ij} = \alpha_0 + \alpha_1 \ln X_{1ij} + \alpha_2 \ln X_{2ij} + \alpha_3 \ln X_{3ij} + \alpha_4 X_{4ij} + \alpha_5 X_{5ij} + \alpha_6 X_{6ij} + \alpha 7\, X_{7ij} + V_{ij} - U_{ij} \qquad (5)$$

The subscripts i and j refer to the ith farmers and jth observation respectively while,

Y	=	total farm output of rice (kg)
X_1	=	cultivated land area for rice (ha)
X_2	=	sum of family labour (persons days)
X_3	=	sum of hired labour (persons days)
X_4	=	quantity of seed planted (kg)
X_5	=	quantity of fertilizer used (kg)
X_6	=	quantity of herbicides used (litres)
X_7	=	age of farmers
V_{it}	=	a random error term with normal distribution $N(0, \delta^2)$
U_{ij}	=	a non-negative random variables called technical inefficiency effects associated with the technical inefficiency of production of farmers involved.
ln	=	the natural logarithm (i.e. to base e).
$\alpha_0 - \alpha_8$	=	parameters to be estimated.

This model was estimated for the two technology groups. Estimation of equation (5) was accomplished by Maximum Likelihood Estimation (MLE) available in Frontier 4.1 developed by Coelli (1996) and has been used extensively by various authors in estimating technical efficiency among crop farmers. Thus, following Aigner, et al (1977) in which $V_1 \sim N(0, \delta_V^2)$ and $U_i \sim |N(0, \delta_u^2)|$, the following log likelihood function could be obtained:

$$InX = \sum iInLi = \sum i\left[-In\delta - \frac{1}{2}In\left(\frac{2}{\prod}\right) - \left(\frac{\varepsilon i}{\delta}\right) + In\theta\left(\frac{-\varepsilon\lambda}{\delta}\right)\right] \quad (6)$$

where i = number of observations, $\delta = (\delta_V^2 + \delta u^2)^{1/2}$

$\lambda = \delta u/\delta v$, $\varepsilon i = Vi - Ui$ and θ is the normal distribution.

In addition to determining farmers' technical efficiency in rice production, the study also went ahead to identify the determinants of farmers' technical efficiency in terms of socio-economic variables and as such an inefficiency model was specified to examine the effect of these variables (z) on the technical efficiency (u_i) of the farmers in rice production. The model which assumes that the inefficiency effects are independently distributed having N $(0,\sigma_u^2)$ distribution and mean u_{it} (Coelli and Batesse 1996) is of the form:

$$u_i = \delta_o + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 \quad (7)$$

Where:

Z_1 = education of the farmer (1 = formal education, 0 =otherwise)
Z_2 = number of contact with extension agent per cropping season
Z_3 = years of farming experience (rice only)
Z_4 = household size

4. Results and Discussions

4.1 Input and socio-economic variables of rice farmers by technology

Average input use among the sampled farmers is presented in Table1. Most of the rice farmers are of small to medium scale categories. The average farm size among the traditional rice farmers was 2.59ha while that of improved technology farmers was 6.52ha. The traditional technology rice farmers made use of 105persons days of family labour per hectare against 45 person's days per hectare by the improved technology rice farmers. Similarly, the traditional technology rice farmers used more hired labour per hectare. The average hired labour use was estimated to be 13 and 6 person's days per hectare respectively for traditional technology and improved technology rice farmers. The amount of person's days of labour recorded in each case for the two technology groups is a clear indication that Nigerian agriculture is still highly labour intensive.

Though the recommended seed rate per hectare of upland and lowland rice production system was put at 100kg/ha by (IRRI, 1995), the traditional technology rice farmers planted about 50kg/ha while their improved technology counterparts planted about half of what they planted (27kg/ha). This has a lot of implication for output and eventually for yield. During the 2003 rice production season, an average of 90kg/ha of fertilizer was applied by the traditional technology rice farmers while the improved technology rice farmers applied about 170kg/ha. In both cases, they fell below the recommended rate of 250-350kk/ha for upland and lowland swamp production system. This has serious effects on yield. In the face of scarcity and increasing wage rate of farm labour, the use of herbicides has been observed as a major labour saving device as the labour requirement for weeding always account for a higher proportion of the total farm labour cost in rice production. An average of 1.30litre/ha of herbicide was applied by the traditional technology rice farmers as against 1.0litre/ha recorded by the improved technology rice farmers. The higher rate recorded among the tradition technology farmers could be attributed to the susceptibility of the traditional rice varieties to diseases infection as a result of their low level of disease resistance.

The average age of traditional technology rice farmers was estimated to be 42 years while that of the improved technology was 45 years. In either case, the average age is tending towards the declining productivity class of greater than 50 years. The implication of this is that except the occupation witnessed the injection of young able men, in the next one decade, many of these farmers would have reached the declining productivity level and rice production in the country will suffer a set back. Average year of schooling for the traditional technology rice farmers was 7 years while that of the improved technology was 8 years. This low level of education will no doubt affect the level of technology adoption and skill acquisition. It will also constitute blocks or drain to extension activities. The traditional technology rice farmers recorded 4 visits during the cropping season while the improved technology farmers recorded 6 visits. The higher number of visit recorded by the improved technology farmers is an indication of the need for more training in order to cope with new technology. Farmers with improved technology are more experienced than the traditional technology farmers with average of 22 and 15 years of farming experience respectively. The higher level of experience of the improved technology farmers explained why they were venturesome innovators. Household members of farmers using improved technology were more than their traditional counterparts. However, this higher size does not translate to higher use of family labour as shown earlier.

Table 2: Per hectare average input use, output and socio-economic characteristics of farmers by technology per hectare

Variable input	Traditional technology	Improved technology
Yield (kg/ha)	1,093	1, 371
Family labour (persons days)	105.00	45.00
Hired labour (persons days)	13.00	6.00
Herbicide (litres)	1.29	1.00
Seeds (kg)	51.50	27.00
Fertilizer (kg)	90.00	172.00
Farm size	2.59	6.52
Age in years	42	45
Years of education	7	8
Number of contact with extension agents	4	6
Years of experience	15	22
Household size	8	10

Source: Computed from field data, 2004

The Levene's test for equality of variances and the t-test for equality of means were carried out to establish whether significant differences exist in the variation in input use and socio-economic characteristics between the traditional and improved rice variety farmers. For input use, the Levene's test showed that except for hired labour, variations in the level of input use were significant at ($p< 0.05$) and equal within each group and between the two groups. The test for equality of means for the various inputs between the two groups showed no significant difference in the estimated means for family and hired labour between the two groups of farmers. This may be the reason for the relative equality in the average technical efficiency observed in the frontier analysis since labour constitutes more than 70 of farm inputs in rice farming in Nigeria. Farmers experience showed equal variance within each group and between the two groups, while all other socio-economic variables exhibited different variances between the two groups. Similarly, the test for equality of means also revealed that while there was no significant difference in the estimated mean for age, education and contact with extension agents between the two groups of farmers, the equality of means for experience and household size was highly significant.

4.2 Technology and technical efficiency of farmers

Table3 presents the result of the maximum likelihood estimates for the two groups of farmers while the distribution of technical efficiency among the farmers was presented in Table 4. From Table 3, farm size, hired labour, herbicide and seed contributed significantly to the technical efficiency of the farmers. For the improved technology rice farmers, only three of the variables, farm size, hired labour and herbicides are significant. This indicated that the quality of seed planted was more important than the absolute quantity. Also the significant use of herbicide is an indication of the increased response of improved rice varieties to effective weed control. In both technologies, farm size was found to be significant, an indication of low use of yield enhancing technology and inputs in rice cultivation in Nigeria. The coefficient of farm size was 1.07 and 0.88 respectively for traditional and improved rice variety farmers. This, however, pose some challenges of environmental sustainability of the cultivation method. Though the use of hired labour and herbicides were found to contribute significantly to technical efficiency among the traditional rice variety farmers, their corresponding elasticities did not suggest that increased used of these input will yield more than proportionate increase in output. It was also observed that fertilizer which is the most critical input in rice cultivation was not significant. This underscores the low use of the input as a result of the erratic supply occasioned by continuous subsidy on the input. Traditional technology farmers used on the average 90kg of fertilizer per hectare as against the recommended 200 -250kg/ha (Table 2).

Table 3: Maximum likelihood estimates of frontier model for traditional and improved technology farmers

Variables	Coefficient		Standard Error		T-ratio	
	Traditional	Improved	Traditional	Improved	Traditional	Improved
Constant	0.297	0.35	0.029	0.038	10.24	9.21
Farm size	1.07	0.88	0.04	0.11	23.56***	7.87***
Family labour	0.06	-0.08	0.04	0.09	1.28	0.99
Hired labour	0.03	-0.07	0.02	0.04	1.72*	1.67*
Herbicide	0.13	1.00	0.04	0.05	3.01***	1.89**
Seed	0.12	1.00	0.04	0.09	2.97***	1.08
Fertilizer	0.03	0.03	0.04	0.06	0.82	0.42
Age	0.07	0.03	0.17	0.20	0.41	0.13
Education	-0.13	-0.01	0.08	0.02	1.65*	0.45
Contact with EAs	-0.03	-0.02	-0.02	0.02	1.32	1.26
Experience	0.03	0.001	0.02	0.01	1.84*	0.19
Household size	-0.03	-0.06	0.02	0.04	1.48	1.37
Sigma square (σ^2)	0.24	0.05	0.12	0.03	2.05***	1.51
Gamma (γ)	0.93	0.83	0.04	0.12	25.68***	6.69***

Source: Computed from Field Data, 2004

EAs= Extension Agents

***Significant at $P \leq 0.01$
** Significant at $P \leq 0.05$
* Significant at $P \leq 0.10$

The result of the inefficiency effects model showed that only education and experience have significant effect on the level of technical efficiency traditional technology farmers. However, all the included variables except experience were correctly signed. On the other hand, none of the included socio-economic variables have significant effects on the technical efficiency of the improved technology farmers. Thus, the technical inefficiency of the farmers might have been accounted for by other natural and environmental factors which are not captured in the model. These factors include land quality, weather, labour quality, diseases and pest infestation and so on. Three of the variables, education, contact with extension agent and household size were however, correctly signed. Result of the Levene's Test for equality of variances indicated that there was no significant variation in technical efficiency within each of the group and between the two groups. Similarly, the t-test for equality of means between the two groups shows that there was no significant difference between the two mean.

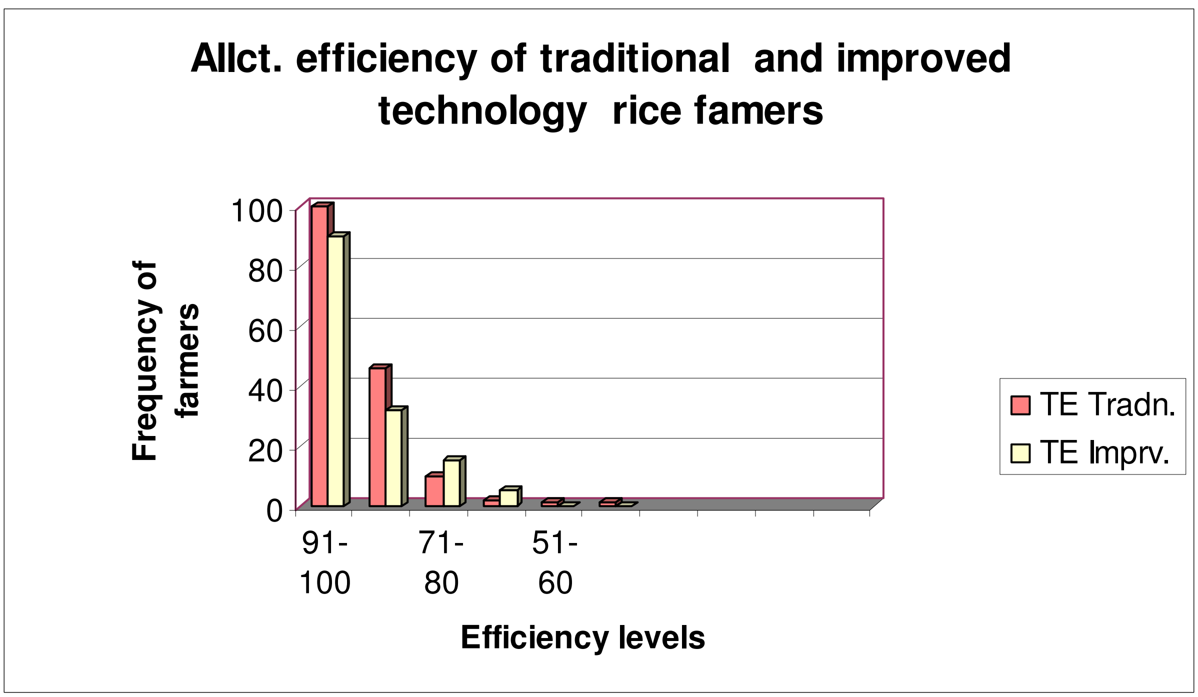
The frequency distribution of technical efficiency presented in Table 4 showed that about 73 % of the traditional rice varieties farmers had their technical efficiency above 0.90 as against 63% recorded for the improved rice varieties farmers which indicated that there is very little opportunity to increase technical efficiency among these groups of farmers. In fact the average technical efficiency of 0.9 showed that, given the level of technology of this group of farmers little can be done to increase their production capacity. With an average yield of 1.2tons per hectare, it is obvious that in spite of the high technical efficiency within the context of the country, they are far behind when compare with other countries like Cote d' Ivoire and Senegal with average yield of over 3.0tons per hectare. The fact that this result was not significantly different between the two group call for technology policy concern on rice production in the country. The following explanation may however, be offer for the result obtained in this study:

First, it is possible that these farmers found it very difficult to distinguish between the so called improved rice varieties and the traditional varieties. In other words some of the varieties considered by the farmers as traditional varieties might be improved varieties that have been domesticated for appreciable length of time. Second, the improved varieties may not possessed the required traits for higher yield as compared to what obtained in other countries like Cote d' Ivoire and Senegal. Third, the low use of critical inputs such as fertilizer and herbicides may have seriously undermined the yield of the improved technology farmers. Finally, the improved varieties might not be well adapted to the environment. For example, where an upland improved variety is planted in the lowland field, the yield may be seriously hampered.

Table 4: Frequency distribution of technical efficiency among traditional and improved technology Rice Farmers

Range of Technical Efficiency	Frequency		Absolute percentage	
	Traditional	Improved	Traditional	Improved
< 50	1	0	0.60	0
50 < 60	1	0	0.60	0
60 < 70	2	5	1.25	3.52
70 < 80	10	15	6.25	10.56
80 < 90	46	32	29.00	22.54
90 < 100	100	90	72.50	63.38
Total	160	142	100.00	100.00
Mean	0.90	0.91		

Source: Computed from Field Data, 2004



5. Conclusion

One major findings emanating from this study is the fact that rice output expansion in Nigeria has been mainly through area expansion as most of the critical inputs did not significantly influence technical efficiency. Also labour and fertilizer were identified as major inputs in rice production in Nigeria. Therefore, policy attention should be directed towards providing labour saving technology to ease farm operation. Also procurement and distribution of fertilizer should be completely liberalized. The equality in technical efficiency between the two farm groups required further investigation into factors influencing technology adoption among Nigerian rice farmers. This kind of study will require different methodology and analytical approach. It will, however, provide more insight and useful explanations as regards the issue of technology diffusion and while some farmers prefer to steak into the traditional seed varieties in spite of lower yield. Such study will also expose some of the reasons for the non-significant difference in technical efficiency observed between the two groups of farmers which cannot be adequately provided in this study as a result of the limitation in the scope of the study.

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