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TECHNICAL EFFICIENCY DIFFERENTIALS IN RICE PRODUCTION TECHNOLOGIES IN NIGERIA

Olorunfemi O. Ogundele and Victor O. Okoruwa

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Technical efficiency differentials in rice production technologies in Nigeria

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List of acronyms and abbreviations

ADP	Agricultural Development Project
ARGM	African rice gall midge
FAO	Food and Agricultural Organization
FMARD	Federal Ministry of Agriculture and Rural Development
IART	Institute of Agricultural Research and Training
IITA	International Institute of Tropical Agriculture
IRRI	International Rice Research Institute
LDCs	Less developed countries
MLE	Maximum likelihood estimate
NAGRAB	National Centre for Genetic Research and Biotechnology
NERICA	New Rice for African Countries
NISER	Nigerian Institute of Social and Economic Research
PCU	Project Coordinating Unit
WARDA	West African Rice Development Association.

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Abstract

This study examined technical efficiency differentials between farmers planting traditional rice varieties and those planting improved varieties in Nigeria. The study used a multistage random sampling procedure 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 analytical techniques involved descriptive statistics and estimation of technical efficiency following maximum likelihood estimation (MLE) procedure available in Frontier 4.1. The various tests of statistics carried out included the T-test for equality of means for input use, socio-economic characteristics and technical efficiency between the two groups of farmers, and the Levene test for equality of variances.

Results from these analyses showed 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. Other variables that tend to contribute to technical efficiency are hired labour, herbicides and seeds. Fertilizer, the most critical input required for increased production, was found not to have contributed significantly to technical efficiency. The estimated average technical efficiencies for the two groups were correspondingly high (>0.90), which indicated that there is little opportunity for increased efficiency given the present state of technology. The test of hypothesis on the differentials in technical efficiency between the two groups of farmers showed that there was no absolute differential. The lack of differential in technical efficiency between the two groups puts to question the much expected impact of the decades of rice development programmes in Nigeria. This study therefore recommendes that all forms of obstacles that could constrain the use of inputs should be removed. This should include complete liberalization of the procurement and distribution of such input and the development of some low-cost labour saving technologies to ease labour constraints on farms.

1. Introduction

The Nigerian rice sector is special within the West Africa context. First, rice is primarily a cash crop in Nigeria (produced primarily for the market). Therefore, in rice producing areas, the enterprise provides employment for more than 80% of the inhabitants in various activities along the production/distribution chain from cultivation to consumption. Some remarkable developments have also taken place in the sector particularly in the last ten years. Both production and consumption have increased during the period, although the increased production was not sufficient to match the consumption increase, with rice imports making up the shortfall. Because rice is now a structural component of the Nigerian diet and rice imports make an important share of Nigerian agricultural imports, there is considerable political interest in increasing the consumption of local rice. This has made rice a highly political commodity in Nigeria.

Despite the importance of Nigerian rice production even within the West African subregion, comprehensive and up-to-date information about the level of resource use efficiencies of the farmers is still lacking. The few available studies were either system based or location specific. Moreover, most of these studies focused primarily on the profitability of the enterprise, without in-depth enquiry into efficiencies of farmers and factors that determine their levels of efficiency. To address that gap, this study was designed to determine technical efficiency in rice production in Nigeria, covering the two major rice ecologies in the country (upland and lowland rainfed ecologies). The technology issue was also a factor in capturing the differentials in technical efficiency between farmers planting improved rice varieties and those planting traditional varieties.

The problem

Rice is perhaps the world's most important food crop, being the staple food of over 50% of the world population, particularly in India, China, and a number of other countries in Africa and Asia. In Africa, particularly in the 1980s, Egypt and Malagasy Republic account for 62% of all rice produced (Chuta, 1984). Recently, important and major changes have led to structural increases in rice consumption in the West African subregion. Since 1973, regional demand has grown at an annual rate of 6%, driven by a combination of population growth and substitution away from traditional coarse grains. The consumption of traditional cereals, mainly sorghum and millet, has fallen by 12kg per capita, and their share in cereals used as food dropped from 61% in the early 1970s to 49% in the early 1990s. In contrast, the share of rice in cereals consumed grew from

15% to 26% over the same period. (Akpokodje et al., 2002). Growth in regional rice consumption remains high. The FAO projects the annual growth rate to 4.55 beyond the year 2000. This means that the total volume of rice consumed in West Africa is likely to increase by 70% over this decade. In Nigeria, the demand for rice has been increasing at a much faster rate than in any other African country since the mid 1970s (FAO, 2001). For example, during the 1960s, Nigeria had the lowest per capita annual consumption of rice in the subregion at 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 averaged 18kg and then 22kg in 1995–2000. In an apparent move to respond to the increased per capita consumption of rice in Nigeria, local production boomed, averaging 9.3% per annum. These increases have been traced to vast expansion of rice area at an annual average of 7.9% and to a lesser extent to increases in rice yield of 1.4% per annum. In spite of this, the production increase was not sufficient to match the consumption increase.

In a bid to address the demand/supply gap, governments have at various times come up with policies and programmes. It is observed that these policies have not been consistent. The erratic policies reflect the dilemma of securing cheap rice for consumers and a fair price for the producers. Thus, the fluctuations in policy and the limited capacity of the Nigerian rice sector to match domestic demand have raised a number of pertinent questions both in policy circles and among researchers. For example, what are the factors explaining why domestic rice production lags 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 rainfed rice in Nigeria is 1.8 ton per hactare, while that of the irrigation system is 3.0 ton/ha (PCU, 2002). This is very low when compared with 3.0 ton/ha from upland and lowland systems and 7.0 ton/ha from irrigation systems in places like Cote d'Ivoire and Senegal (WARDA and NISER, 2001). It therefore appears that rice farmers in Nigeria are not getting maximum return from the resources committed to the enterprise. 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 that a number of rice development programmes such as varietal 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.

Objectives and hypotheses

The main objective of this study is to establish the differentials in technical efficiency between farmers planting improved rice varieties and those planting traditional varieties in Nigeria. In order to achieve this, the following specific objectives were pursued:

- Analyse input use and socioeconomic characteristics of the farmers.
- Determine the technical efficiency of the rice farmers and establish the differentials in technical efficiency between the two groups of farmers.

- Examine factors that determine the level of technical efficiency of the farmers.

The following hypotheses were tested:

1. H0: That there is no significant difference in the level of input use between farmers planting traditional rice varieties and those planting improved varieties.
2. H0: That there is no significant difference in the socioeconomic characteristics of the two groups of farmers.
3. H0: That there is no absolute differential in technical efficiency between farmers using traditional technology and those using improved technology.

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

Indicator	Mean (1961–75) tons	Mean (1976–82) tons	Mean (1983–85) tons	Mean (1995–2000) tons
Nigeria				
Production	332,800	806,222	230,6794	318,9833
Import	2,036	420,756	334,974	525,307
Self-reliance ratio	99%	54%	77%	79%
Total consumption	178,199	833,640	1,599,609	2,248,113
Per capita consumption	3.0	12.0	18	22
West Africa without Nigeria				
Production	1,779,376	2,344,073	2,822,635	4,041,384
Import	416,183	894,073	1,760,884	2,107,146
Self-reliance ratio	65%	56%	42%	50%
Total consumption	1,178,753	1,950,821	2,973,885	3,985,721
Per capita consumption	21.0	27.0	30.0	34

Source: Computed from FAO – AGROSTAT (2000)

Rice production trends in Nigeria

Rice production started in Nigeria in 1500 BC with the low-yielding indigenous red grain species *Oryza glaberrima* Stued that was widely grown in the Niger Delta area (Hardcastle, 1959). The high-yielding white grain, *O. sativa L.,* was introduced about 1890 and by 1960 accounted for more than 60% of the rice grown in the country. Today, rice is cultivated in virtually all the agro-ecological zones in Nigeria, but on a relatively small scale. In 2000, out of about 25 million hectares of land cultivated to various food crops, only about 6.7% was under rice (PCU, 2001). The trend in production shows that paddy rice first experienced a boom in the 1965–1970 period, when average output stood at 321,000 tons (Table 2). During this period, average area cultivated to rice stood at 234,000 hectares while average national yield was 1.36 tons/ha. Another significant improvement in rice production in Nigeria was recorded in 1986–1990, when output increased to over 2 million tons while average area cultivated and yield rose to 1,069,200 hectares and 2,096 tons/ha, respectively. Throughout the 1980s, rice output and yield increased. But in the 1991–1995 period, while rice output increased, yield of rice declined, which implies that the increased output was a result of extensive land cultivation.

There was also great disparity among the states of the federation in rice production in terms of both output and yield. In 2000, Kaduna State was the largest producer of rice, accounting for about 22% of the country's rice output. This was followed by Niger State (16%), Benue State (10%) and Taraba State (7%) (FMARD, 2001). Great variations also exist in terms of yield. The average national rice yield during the dry season (3.05 tons/ha) was higher than that of the wet season (1.85 ton/ha).

Table 2: Rice production trends in Nigeria (1961–2000)

Period	Average area cultivated (hectare)	Average output (tons)	Average yield (tons/ha)
1961-1965	179,200	207,200	1.147
1966-1970	234,000	321,000	1.360
1971-1975	288,800	470,200	1.670
1976-1980	332,000	596,200	1.710
1981-1985	630,000	1, 300,200	2.063
1986-1990	1,06,200	2,216,064	2.090
1991-1995	1,678,000	2,979,600	1.783
1996-2000	1,742,582	3,011,028	1.733

Source: PCU, FMARD, Nigeria (2002).

Efforts to meet rice production needs in Nigeria

Active and systematic rice research started in the country in 1953 with the establishment of the Federal Rice Station at Badeggi in Niger State, now the headquarters of the National Cereals Research Institute (NCRI). The focus for rice research at the station was the development of varieties with improved grain quality, uniform shape and sizes appropriate for minimal breakage during milling. These aims were achieved mainly through introduction and adaptation (Imolehin, 1991a). Between 1954 and 1970, 13 improved rice varieties, comprising two upland, eight shallow swamp and three deep-flooded rices, were released to Nigerian farmers. From 1971 onwards, research activities on rice focused on developing high-yielding and disease resistant varieties, the efficient use of nutrients, and good soil management. These aims were achieved through introduction, adaptation and hybridization (Imolehin, 1991a). Efforts resulted in the release of 16 rice varieties, with the desired traits for pest and disease resistance, nutrition and yield, to Nigerian rice farmers between 1971 and 1984. The 16 varieties comprised one upland, 12 lowland and three deep-water ecology rice. From 1985 to 1989, an additional 14 high-yielding blast-resistant varieties, including six upland and three lowland varieties, were released. From 1990 to date 11 more rice varieties, comprising eight uplands and three shallow swamp varieties, have been released (FAO, 2000). Thus, from 1954 to 2002 a total of 54 rice varieties have been released to serve the different ecologies and other specific needs in Nigeria.

A remarkable effort to develop suitable rice varieties for Nigerian farmers was made in 1997 with the release of FARO 51, a variety that is resistant to the African rice gall midge (ARGM) *Orseolia oryzivora* (World Bank, 1997a). When grown in an ARGM-endemic area of Abakaliki, the variety exceeded the yields from farmers' varieties by 26% (FAO, 2000). Recently, WARDA has developed an improved variety mainly for upland farmers. The variety is known as NERICA (New rice for African countries) and it is observed that the yield could be as high as 3.0 tons per hectare or more with strict compliance with recommendations. This variety has just been released, however, and some time is required for adoption before the technology can be evaluated. Increased rice production is expected to be achieved effectively when Nigerian farmers in all the ecological zones of the country utilize improved rice varieties, along with appropriate cultural and management practices.

A second part of the research effort is germplasm collection and conservation. The idea is to ensure the preservation of diverse genetic information that can be tapped in a variety of ways and used to evolve varieties with desirable characters. The rice breeding programme started to collect rice germplasm from Nigeria and the rest of the world, an activity made possible by the active collaboration of international and national institutes working on rice, including the International Rice Research Institute (IRRI), the International Network for Genetic Evaluation of Rice for Africa (INGER-Africa), the West Africa Rice Development Association (WARDA), the International Institute of Tropical Agriculture (IITA), and the Institute for Agricultural Research and Training (IART) in Ibadan. Some of the rice germplasm collected is conserved at the institute in freezers, but the bulk is stored in IITA's more efficient cold rooms (Imolehin, 1991a).

Since the establishment of the National Centre for Genetic Research and Biotechnology (NAGRAB) at Ibadan, rice germplasm materials have always been conserved there, and it is from there that genetic information is being sourced for routine breeding work. The breeding or adaptation of various types to suit the diverse ecological zones of the country has been possible because of nationally coordinated rice evaluation trials in which newly bred varieties are evaluated for at least three years for desired characteristics. Promising varieties are evaluated further for yield performance in multi location on-farm adaptive research trials across the country before being released to Nigerian farmers (Imolehin, 1991b). Released varieties also have properties that satisfy different consumer preferences in terms of grain type, swelling capacity, amylose content, protein and cooking time.

Policy environment and rice sector development

From an historical perspective, Nigeria's rice policy can be discussed in reference to three important periods. These are the pre-ban, ban and the post-ban periods. These periods reflect the kind of policies put in place that had profound impact on the rice sector. The pre-ban period, the era prior to the introduction of absolute quantitative restriction on rice imports (1971–1985), can also be classified into two: the pre-crisis (1971–1980) and the crisis (1981–1985) periods. The pre-crisis period was largely characterized by liberal policies on rice imports, with some ad hoc policies put in place during times of interim shortages. It corresponds to the launching of various programmes and projects aimed at developing rice production. While more stringent policies were put in place during the crisis period, outright ban was not a major feature. That changed in the ban period (1986–1995), when it was illegal to import rice into the country, although illegal importation of the commodity was going on across the country's borders. During the post-ban period (1995–2000), quantitative restrictions on rice importation were lifted and the country moved into a more liberal trade policy in respect of rice. From 2000 to date, the Federal Government has resorted to constant and upward adjustment of the import tariff on rice, from 50% in 2000 through 75% in 2001 to 100% in 2002. From the beginning of 2003, the tariff was adjusted to 150%.

2. Conceptual framework and literature review

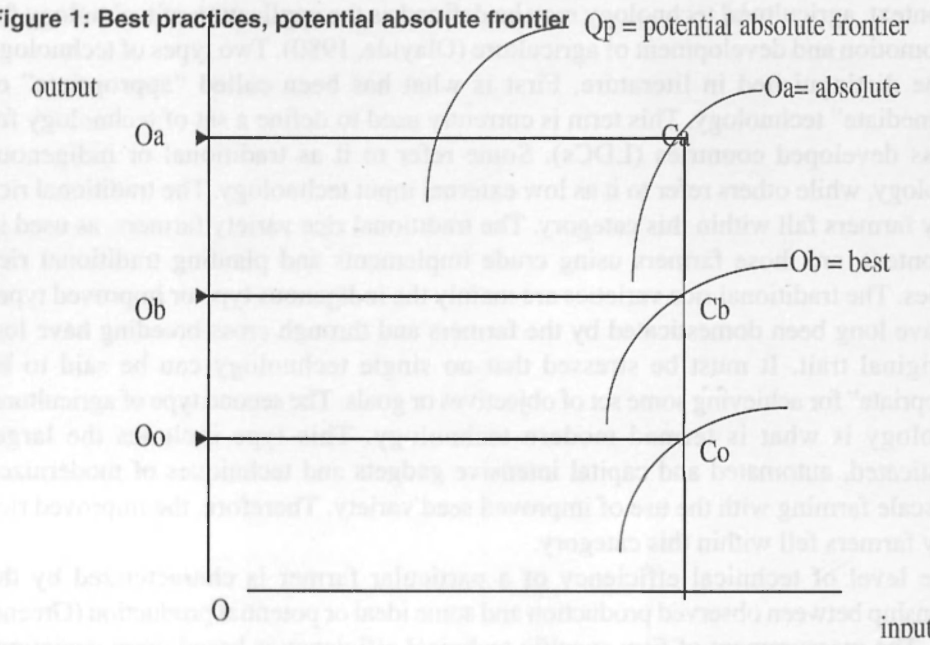
Technology may be defined simply as the systematic application of collective human rationality to the solution of problems through the assertion of control over nature and all kinds of human processes. It is the embodiment and result of systematic, disciplined, cumulative, non accidental and non serendipitous research (Ellul, 1965). In this context, agricultural technology may be defined as the application of technology for the promotion and development of agriculture (Olayide, 1980). Two types of technology may be distinguished in literature. First is what has been called "appropriate" or "intermediate" technology. This term is currently used to define a set of technology for the less developed countries (LDCs). Some refer to it as traditional or indigenous technology, while others refer to it as low external input technology. The traditional rice variety farmers fall within this category. The traditional rice variety farmers, as used in this context, are those farmers using crude implements and planting traditional rice varieties. The traditional rice varieties are mainly the indigenous type or improved types that have long been domesticated by the farmers and through cross breeding have lost the original trait. It must be stressed that no single technology can be said to be "appropriate" for achieving some set of objectives or goals. The second type of agricultural technology is what is termed modern technology. This type includes the large, sophisticated, automated and capital intensive gadgets and techniques of modernized large-scale farming with the use of improved seed variety. Therefore, the improved rice variety farmers fell within this category.

The level of technical efficiency of a particular farmer is characterized by the relationship between observed production and some ideal or potential production (Greene, 1980). 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 (Figure 1).

For example, O_o/O_b in Figure 1 is a comparison of output at points C_o and C_b, each with the same level of input but C_b lying on the best practices frontier function Q_b (passing through a 100%-efficient sample point) whilst C_o lies on Q_o, which represents a locus that is a neutral shift of the frontier Q_b and passes through the point C_o. The concept could be measured relative to other frontiers, for example the absolute frontier function Q_a lying above all sample points. Here, the ratio will be O_o/O_a or a comparison of output at points C_a on O_a and C_o. The potential absolute frontier is also represented by Q_p. The potential absolute frontier, the maximum output obtained from all conceivable observations embodying the current technology (including over all time periods in which adoption takes place), is represented by Q_p which lies above Q_a. Over time, there would be a sequence of absolute frontier function Q_a's (and associated levels of technical efficiency) moving up to the potential absolute frontier function Q_p.

Farrell's (1957) definition of technical efficiency led to the development of methods for estimating the relative technical efficiencies 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)

Figure 1: Best practices, potential absolute frontier



Review of production frontier models

The estimation of production frontiers has proceeded along two general paths: full-frontier, which forces all observations to be on or below the frontier and hence where all deviation from the frontier is attributed to inefficiency, and stochastic frontiers, where deviation from the frontier is decomposed into random components reflecting measurement error and statistical noise, and a component reflecting inefficiency. The estimation of full frontier could be through a non-parametric approach (Meller, 1976) or a parametric approach where a functional form is imposed on the production function and the elements of the parameter vector describing the function are estimated by programming (Aigner and Chu, 1968) or by statistical techniques (Richmond, 1974; Greene, 1980).

The drawback of these techniques is that they are extremely sensitive to outliers. Hence, if the outliers reflect measurement errors they will heavily distort the estimated frontier and the efficiency measures derived from it. The stochastic frontier approach, however, appears superior because it incorporates the traditional random error of regression. In this case the random error, besides capturing the effect of unimportant left out variables and errors of measurement in the dependent variable, would also capture the effect of random breakdown on input supply channels not correlated with the error of the regression. What would have appeared as the major advantage of full frontier models over the stochastic model (i.e., the fact that they provided efficiency indexes for each firm) was later overcome by (Jondrow et al., 1982).

Measurement of efficiency started with Farrell (1957) who, following Debreu (1951) and Koopmas (1951), proposed a division of efficiency into two components: technical efficiency, which represents a firm's ability to produce a maximum level of output from a given level of inputs, and allocative efficiency, which is the ability of a firm to use inputs in optimal proportions, given their respective prices and available technology. The combination of these two measures yields the level of economic efficiency.

There are several approaches to analyse the determinants of technical efficiency from stochastic production frontier functions. One set of authors followed a 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 that are usually firm-specific characteristics. Authors in this category include Pitt and Lee (1981), Kalirajan (1981a), Parikh and Shah (1995), Ben-Belhassen (2000), and Ogundele (2003). While this approach is very simple to handle, the major drawback is that it violates the assumption of the error term. In the stochastic frontier model, the error term (the inefficiency effects) is 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 a 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 a more consistent approach that modelled 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. Authors in this category include Kumbhakar, Ghosh and McGuckin (1991), Reifschneider and Stevenson (1999), Huang and Liu (1994), and Battese and Coelli (1995), who proposed a stochastic frontier production fuction for panel data. Other authors in recent time include Ajibefun, Battese and Daramola (1996), Coelli and Battese (1996), Battese and Sarfaz (1998), Seyoum et al. (1998), Lyubov and Jensen (1998), Ajibefun and Abdulkadri (1999), Weir and Knight (2000), Obwona (2000), and Ajibefun and Daramola (2003).

Factors determining the efficiency of resource use

Studies conducted either in Nigeria or elsewhere have identified several factors affecting the efficiency of resource use by crop farmers. Some of these studies are reviewed in this section. Ogunfowora et al. (1974), in examining resource productivity in traditional agriculture in Kwara State, Nigeria, estimated a Cobb–Douglas production function through a method of ordinary least square (OLS) and discovered that labour and seed inputs were inefficiently utilized. Farm size (scale of operation) and the level of technology were not taken into consideration, however, which made the result too generalized. Using the same Cobb–Douglas production function in Imo State (Oludimu 1987) examined the efficiency of resource use in various farm enterprises and concluded that the efficient use of resources took place only at the rational stage of production (i.e., at the decreasing but positive return to scale stage). Further examination of the independent variable, however, revealed a diminishing marginal return and decreasing return to scale on farm investment and over-utilization of resources. This study suffered the same drawback as the one mentioned earlier . Adesina and Djato (1997) used a normalized profit function to determine the relative efficiency of male and female rice farmers in Côte d'Ivoire. The result of the study showed that the relative degree of efficiency of women was similar to that of men.

Earlier, Lau and Yotopolous (1971) estimated an equation for the profit function in differences in economic efficiency between large and small farms in India and found that small farms attained a higher level of economic efficiency. Sahidu (1974) adopted the Lau–Yotopolous model to sample of Indian wheat farms and came out with a contrary conclusion – that large and small farms exhibited equal economic efficiency in both the technical and price senses. In Pakistan, Khan and Maki (1979) also adopted the Lau–Yotopoulos model to determine the effects of farm size on economic efficiency in two locations, Punjab and Sind. They found that large farms are more efficient than small farms by 18% in Punjab and 51% in Sind. Some studies have also adopted the stochastic frontier approach for efficiency analysis.

Kalirajan (1981b) used a Cobb–Douglas production function to estimate the economic efficiency of farmers growing high-yielding, irrigated rice in India. He compared the small and large farm groups and concluded that there was equal relative economic efficiency in the cultivation of IR20 in rabi season between the groups. Bagi (1982) estimated a stochastic frontier Cobb–Douglas production function to determine whether there were any significant differences in technical efficiencies of crop and mixed enterprise farms in West Tennessee in the USA. The variability of inefficiency effects was found to be highly significant and the mean technical efficiency of mixed enterprise farms was smaller than that of crop farms (0.76 and 0. 85, respectively). Bagi and Huang (1983) estimated a translog stochastic frontier production function using the same farm data as Bagi (1982). The Cobb–Douglas stochastic frontier model was found not to be an adequate representation of the data, given the specification of the translog model for both crop and mixed farms. The mean technical efficiencies of crop and mixed farms were estimated to be 0.73 and 0.67, respectively. Kalirajan and Flinn (1983) used the translog stochastic frontier production function in the analysis of data on 79 rice farmers in Philippines. The individual technical efficiencies ranged from 0.38 to 0.91. In Australia, Battese and Coelli (1988) applied a panel data model in the analysis of technical efficiency in dairy farms in New South Wales and Victoria over three years. The estimated technical efficiencies ranged between 0.55 to 0.93 for New South Wales farms and between 0.39 and 0.93 for Victoria farms. Battese and Tessema (1993) estimated stochastic frontier production functions with time-varying technical inefficiency for Indian farmers. While the results show that technical efficiencies varied widely, the hypothesis of time-invariant technical efficiency is not rejected in one of the three villages. Dawson et al. (1991) used a stochastic production frontier to measure farm-specific technical efficiency in rice farms of Central Luzon, Philippines, and found a narrow range of efficiency – 84–95% – across the 22 farms sampled. In this same study, a comparison was made with measures of technical efficiency using traditional covariance analysis. The results showed that the distributions of efficiencies obtained from both stochastic frontier and covariance analysis approaches are different. Potential gains in technical efficiency are small for the former but are relatively large for the latter, which means that those obtained from the stochastic frontier are preferred. Heshmati and Mulugata (1996) estimated the technical efficiency of Ugandan *matoke* producing farmers and found that the farmers face production technologies with decreasing return to scale. The mean technical efficiency was 65%, but there was no significant variation in technical efficiency with respect to farm size.

Seyoum et al. (1998) investigated the technical efficiency and productivity of maize producers in Ethiopia. The findings show that farmers who participate in a programme of technology demonstration are more technically efficient than farmers who do not. Townsend et al. (1998) used data envelopment analysis to investigate the relationships among farm size, return to scale and productivity among wine producers in South Africa. Their study found that most farmers operate under constant return to scale, with a weak inverse relationship between farm size and productivity.

Ajibefun and Abdulkadri (1999) estimated technical efficiency for food crop farmers under the National Directorate of Employment in Ondo State, Nigeria. The results of the analysis indicated wide variation in the level of technical efficiency, between 0.22 and 0.88. Mochebele and Winter-Nelson (2000) investigated the impact of labour migration on technical efficiency performance of farms in Lesotho. Using the stochastic frontier production, the study found that households that send migrant labour to South African mines are more efficient than households that do not, with mean technical efficiency of 0.36 and 0.24 respectively.

Obwona (2000) estimated a trans log production function to determine technical efficiency differentials between small- and medium-scale tobacco farmers in Uganda using a stochastic frontier approach. The estimated efficiencies were explained by socioeconomic and demographic factors. The results showed that, credit accessibility extension services and farm assets contribute positively towards the improvement of efficiency. One major drawback of this study is the inability of the author to show in clear terms whether there is any differential in efficiency between the two groups of farmers.

Most of the earlier studies cited concentrated on aggregate data and employed relatively simple statistical tools. More importantly, there were no efforts made to quantify the magnitude of the contribution of the various factors affecting productivity.

3. Methodology

This study was conducted in the four major rice producing states in Nigeria: Kaduna, Niger, Ebonyi and Ekiti. These four states jointly accounted for about 70% of the total rice produced in Nigeria between 2000 and 2003 (PCU, 2003). These states also cover the two major rice production ecologies in the country. The ecologies are the upland and the lowland (all rainfed) systems, which jointly accounted for the greater proportion of rice produced in terms of both area and output.

The study uses mainly primary data collected from the rice farmers in the four states based on production activities for 2003. The primary data were collected with the use of structured questionnaires administered to the farmers in the chosen areas of the study. These questionnaires were pre-tested in Ekiti State. Other complementary information such as number of farm families in each local government areas of the state was collected from the Agricultural Development Project (ADP) of the respective states.

Sampling technique

The study used a multi-stage random sampling technique. The first stage was the purposive selection of the four states mentioned above. The second stage involved selection of two rice producing local governments in each state. From each local government, two rice producing villages were randomly selected. It should be noted that the list of the local governments and villages producing rice in each state are readily available at the state ADP. The fourth and final stage was the random selection of 20 farmers from each village, making a total of 320 farmers for the study. The selections were done to cover the various rice ecologies available in each state. The list of farmers in each village is also readily available at the office of the village block extension agent. It is important to mention here that the target of 160 respondents for the traditional technology farmers was met, which represents a 100% response rate; the return in the case of improved technology farmers was a little less than 100%, however. Out of 160 questionnaires distributed, only 142 were retuned, representing about 89%. This did not affect the result of the analysis, as the number of respondents was large enough to permit reasonable comparison.

Model specification

The stochastic frontier model used in this study is a variant of that of Khumbhakar and Heshmati (1995), Yao and Liu (1998), and Ogundele (2003). The model specified output (Y) as a function of inputs (X) and a disturbance term (μ):

$$Y_i = h(X_{ij}\ X_{ij}\ ....,\ X_{ij};\ A;\ \varepsilon_i) \tag{1}$$

where Y_i is output by farmer i, X_{ij} is input *j* of *n* inputs, and *A* is a vector of parameters. The disturbance term consist of two components, $\varepsilon_i = V_i - U_i$, where $V_i \sim N(0, \sigma_v^2)$, and U_i, which is a one-sided error term. The two errors, V_i and U_i, are assumed to be independently distributed. The term V_i is symmetric, allows random variation of the production function across farms, and captures the effects of statistical noise, measurement error and exogenous shocks beyond the control of the producing unit. The one-sided term, U_i, represents technical inefficiency (TI) relative to the stochastic frontier. If $U_i = 0$, production lies on the stochastic frontier and production is technically efficient; if $U_i > 0$, production lies below the frontier and is inefficient.

The error term U_i is usually assumed to follow one of three possible distributions (Lee, 1983; Schmidt and Lin, 1984; Bauer, 1990): (a) half-normal, i.e., $|N(0, \sigma_u^2)|$; (b) exponential $Exp(\mu_u, \sigma_u^2)$; and (c) truncated normal at zero $N(\mu_u, \sigma_u^2)$. Because the estimates of technical efficiency are similar for each distribution, half-normal and truncated normal could be used. Following Jondrow et al. (1982), technical inefficiency (TI) for each observation is calculated as the expected value of U_i conditional on $\varepsilon_i = V_i - U_i$:

$$TI = E(U/\varepsilon) = \frac{\sigma_u \sigma_v}{\sigma}\left[\frac{g\dfrac{(\varepsilon\lambda)}{\delta}}{1 - G\dfrac{(\varepsilon\lambda)}{\delta}} - \frac{(\varepsilon\lambda)}{\delta}\right] \tag{2}$$

where *E* is the expectations operator, *g(•)* and *G(•)* are the standard normal density and distribution functions, $\sigma = (\sigma^2 + \sigma_u^2)^2$, and $\lambda = \delta_u / \delta_v$

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

$$\ln Y_{ij} = \alpha_0 + \alpha_1 \ln X_{1ij} + \alpha_2 \ln X_{2ij} + \alpha_3 \ln X_{3ij} + \alpha_4 X_{4ij} + \alpha_5 X_{5ij} + \alpha_6 X_{6ij} + \alpha_7 X_{7ij} + V_{ij} - U_{ij} \tag{3}$$

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 (person days)
X_3 = sum of hired labour (person 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 variable 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

Model estimation

This model was applied to the two technology groups. Estimation of Equation 3 was accomplished by maximum likelihood estimation (MLE) available in Frontier 4.1; this technique was 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 $V_I \sim N(0, \delta_V^2)$ and $U_i \sim |N(0, \delta_u^2)|$, the following log likelihood function could be obtained:

$$InX = \sum iInLi = \sum i\left[-In\delta - \frac{1}{2}In\left(\frac{2}{\prod}\right) - \left(\frac{\varepsilon i}{\delta}\right) + In\theta\left(\frac{-\varepsilon\lambda}{\delta}\right)\right] \quad (4)$$

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.

Inefficiency effects and socioeconomic model

Average level of technical efficiency measured by mode of truncated normal distribution (i.e., U_{it}) has been assumed (Dawson et al., 1991; Kumbhakar and Heshmati, 1995; Yao and Liu, 1998) to be a function of socioeconomic factors as shown in the relationship:

$$U_{it} = \beta_0 + \beta_1 R_{1it} + \beta_2 R_{2it} + \beta_3 R_{3it} + \beta_4 R_{4it\ t} \quad (5)$$

where:

R_1 = education of the farmer dummy; 1 for formal education, 0 otherwise
R_2 = number of contact with extension agent per cropping season
R_3 = years of farming experience (rice only)
R_4 = household size

Estimation of the model was accomplished through a joint estimation of the technical efficiency model as specified in Coelli (1996).

4. Results and discussion

The study found that technology plays a very significant role in determining the levels of technical efficiency of Nigerian rice farmers. However, where the producing unit did not comply strictly with recommendations, the results were not up to expectations. Apart from the technical characteristics of the production process and changes in relative input-output prices, other factors that were found to significantly influence the average level of efficiency and productivity of farmers are the socioeconomic characteristics of the farmers, including age, education and level of experience.

Input use and socioeconomic variables of rice farmers by technology

Adoption of improved technologies can lead to the desired result in agricultural production only if farmers comply with the recommendations and requirements of the technologies, in terms of input use and timing of operations. Any significant deviation from the recommended amount of a particular input can result in lower yields. This section examines critically the amount of inputs committed to rice production in the survey areas during the 2003 rice production season (main season). The data were disaggregated into farmers using traditional and improved technology. The analysis involved computation of means, standard variation, standard error of means and variances, while various tests were carried out to ascertain the quality of data and level of significant difference in the estimates from the two sets of technology data. The various tests included the One-sample T-test, Levene's test for equality of variances and independent sample T-test for equality of means.

The traditional technology farmers are those farmers using hoes and cutlasses and planting traditional rice varieties. These traditional varieties were domesticated by the farming communities long ago, so that farmers have gotten used to them and are not ready to abandon them. The improved technology rice farmers, on the other hand, are the medium- to large-scale farmers who adopted mechanized rice cultivation and planted the improved seed varieties. The improved seed varieties are mainly the FARO types developed by the research institutes in the country. They have been subjected to various field trials and were released to the farmers through the extension system of the state agricultural development programmes (ADPs).

Land area cultivated or farm size (hectare)

Farm sizes in Nigeria have been described as small, medium or large scale, if they fall into categories of less than 5ha, between 5ha and 10ha, or more than 10ha, respectively (Upton, 1972). Most of the rice farmers in Nigeria are of small to medium scale categories as can be seen in Table 3. While the average farm size among the traditional rice farmers was 2.59ha, that of improved technology farmers was 6.52ha. Olaf et al. (2002) reported an average of 3.30ha in a study carried out on rice production in Nigeria. The average farm size that could be cultivated by a rice farmer irrespective of the technology depends on the availability of land, the ownership structure, availability of labour input and the production ecology.

Table 3: Per hectare average input use and output by technology

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
Pesticide (litres)	1.29	1.00
Seeds (kg)	51.50	27.00
Fertilizer (kg)	90.00	172.00
Average farm size	2.59	6.52

Source: Computed from field data, 2004.

Labour (person-days)

Labour constitutes the most important input into smallholder agricultural production in Nigeria. Thus, any constraint to the cost and availability of labour is also detrimental to farm productivity. Labour input can be sourced from within the family (family labour), from the commercial pool in the labour market (hired labour) and from among other farmers (group labour). However, family labour constituted the major proportion of the aggregate labour use in Nigerian agriculture. The amount of person-days of family labour that can be engaged by rice farmers will depend on the household size, the age structure of the household and the primary occupation of the household members. Where family labour is in short supply, farmers resort to the alternative, which is hired labour. But, as the paid component of labour input, hired labour constitutes a greater constraint to agricultural production than the other categories of labour. Factors such as urbanization, general increase in the price level, rural–urban migration and industrialization tend to have a negative impact on the availability and cost of hired labour. Thus, the level of utilization and cost of hired labour is a reflection of its scarcity value and/or the availability of alternative sources of labour. The amount of person-days of hired labour that can be committed to production by rice farmers will therefore depend on the availability of hired labour, the farm wage rate, the nature of the farm operation and the period of the year. Table 3 shows that the traditional technology rice farmers made use of 105 person-days of family labour per hectare, against 45 person-days per hectare for 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-days per hectare, respectively, for traditional technology and improved technology rice farmers. In either case, the amount of person-days of labour is a clear indication that Nigerian agriculture is still highly labour intensive.

Quantity of seed planted (kg)

The quantity and type of seed planted by rice farmers depend on the production system, size of the farm, availability of the seed varieties, price per kg, the technology available to the farmer, ability of the farmer to take risks and the suitability of the variety to a particular environment. The recommended amount of seed per hectare of upland and lowland rice production system was put at 100kg/ha (IRRI, 1995). This study found that the traditional technology rice farmers planted about 50kg/ha, while their improved technology counterparts planted about half of that amount (27kg/ha). This has a lot of implications for output and eventually for yield.

Fertilizer application (kg)

Fertilizer is known to be one of the most critical inputs in rice production because of the high response of the crop to fertilizer application. The two major types of fertilizer are organic and inorganic fertilizer. Organic fertilizers are derived from the decay and decomposition of organic matter. The use of organic fertilizer has been highly encouraged among rice farmers because it is environmentally friendly with no residual effects. However, because of the low rate of decomposition and the delay in the release of the constituent nutrients for plant use, its use has been very unpopular. Hence, the most widely used fertilizers among the rice farmers are the inorganic fertilizers, which are manufactured products and are of various types. The most popular among them are the NPK and urea. These fertilizers are known for the fast release of their constituent nutrients. Owing to their scarcity, however, many farmers resort to the use of organic fertilizers. 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. Both cases fell well below the recommended rate of 250–350kg per hactare for upland and lowland swamp production system. This has serious effects on yield.

Pesticide application (litre/ha)

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 accounts for a high proportion of the total farm labour cost in rice production. Rice, like other grains, requires prompt application of agrochemicals such as insecticides and herbicides to check the menace of pest and disease infestation that may occur as a result of overgrowth of weeds. Among common problems are caused by the African rice gall midge (ARGM) and rice blast.

Table 3 shows that an average of 1.30 litre/ha of herbicide was applied by the traditional technology rice farmers as against 1.0 litre/ha recorded by the improved technology rice farmers. The higher rate recorded among the traditional technology farmers could be attributed to the susceptibility of the traditional rice varieties to disease infection as a result of their low level of disease resistance.

Technology and socioeconomic characteristics of farmers

A selection of socioeconomic characteristics of the rice farmers was examined and their variations between the two technologies under consideration established. These are described in this section, with the result of the descriptive statistics presented in Table 4.

Table 4: Socioeconomic characteristics of farmers by technology

Variables	Traditional technology	Improved technology
Age in years	42	45
Years of education	7	8
Number of contacts with extension agents	4	6
Years of experience	15	22
Household size	8	10

Source: Computed from field data, 2004.

Age of farmers (years)

Most of the farm operations in rice cultivation, such as land clearing, tilling, weeding and harvesting, require a lot of strength and energy. Thus, only those farmers within the productive age group of 20–45 years are likely to possess the necessary strength to carry out these operations. Therefore, as farmers age, there is a tendency that productivity will continue to fall owing to their declining strength. The average age of traditional technology rice farmers was estimated to be 42 years, while that of the improved technology farmers was 45 years (Table 4). In both cases, the average age is tending towards the declining productivity class of greater than 50 years. The implication of this is that unless the occupation witnesses the injection of young able farmers in the next decade, rice production in the country will suffer a setback as the existing farmers would have reached the declining productivity level.

Educational status of farmers (years)

Education plays a significant role in skill acquisition and technology transfer. It enhances technology adoption and the ability of farmers to plan and take risks. Farmers with higher levels of education are likely to be more efficient in the use of inputs than their counterparts with little or no education. The results for the level of education of rice farmers by technology displayed in Table 4 show that a majority of the farmers did not complete secondary education. Many of them did not go beyond primary school, while the few who attempted secondary education did not complete it. The average years of schooling for the traditional technology rice farmers was seven, while that of the improved technology farmers was eight years. This low level of education no doubt affects the level of technology adoption and skill acquisition. It may also constitute a block to the effectiveness of extension activities.

Contact with extension agents (number of visits)

The introduction of Agricultural Development Projects (ADPs) in all states of the federation has boosted extension activities in Nigeria. The ADPs often reach the peasant farmers with various agricultural technologies, which are demonstrated to them through their various programmes by the extension agents. Through the activities of these extension agents, some improved rice varieties developed on experimental farms are now being grown by the peasant farmers. The average number of rice related extension visits during the cropping season was recorded and the result is as shown in Table 4. The traditional technology rice farmers recorded four visits during the cropping season while the improved technology farmers recorded six visits. The higher number of visits recorded by the improved technology farmers is an indication of the deliberate attempt by the government to promote new technologies.

Farming experience (years)

Experience, they say, is the best teacher. Thus, the longer a person stays on a job, the more likely the person is to become an expert. Farming involves a lot of risks and uncertainties, hence, to be competent enough to handle all the vagaries of farming a farmer must have stayed on the farm for quite some time. A farmer who has been growing rice for, say, 10 years is likely to be more knowledgeable about the pattern of rainfall, the incidence of pest and diseases, and other agronomic conditions of the area than a farmer who is just coming into the business irrespective of their level of education. It is obvious from Table 4 that the improved technology farmers are more experienced than the traditional technology farmers, with averages of 22 and 15 years of farming experience, respectively. The higher level of experience of the improved technology farmers helps explain why they were venturesome innovators. The age of a farmer may not necessarily correlate with the years of experience in farming. While some farmers start farming very early in their life, some only take to farming after retiring from wage employment in either public or private service.

Household size of farmers

Household size plays a significant role in subsistence farming in Nigeria where farmers rely on household members for the supply of about 80% of the farm labour requirement. This is particularly so in view of the increasing cost of hired labour and the inability of the farmers to make use of improved mechanical tools either due to high cost or relative smallness of farm sizes. In this regard, it has been observed (Ogundele, 2003) that the impact of household size on productivity depends on the quality and capabilities of the household members, rather than on the sheer magnitude of the household size. A farming household comprises the head of household, the spouse(s), the children, and all other relatives or individuals living and feeding in the same pot with the household head. In several instances, this is usually larger than the conventional family size, which consists of the father, the mother and the children only (the nuclear family). Thus a farming household may include members of the extended family. Sometimes, it may bear a direct correlation with the age of the household head. In other words, as household heads grow older, they may require the assistance of some of their grandchildren in some farm operations, thereby enlarging the household size. From Table 4, the improved technology farmers had larger households than their traditional counterparts, at an average size of 10 and 8, respectively. As shown earlier, however, this larger size does not translate to higher use of family labour. This may result from the fact that with higher output and income they can afford to send their children to school, thereby reducing the number of hands available on the farm, or it may be that many of the household members are dependents.

Test of hypotheses – Empirical Results

Two types of independent sample tests were carried out to establish whether significant differences exist in the variation in input use and socioeconomic characteristics between the traditional and improved rice variety farmers. The first was the Levene's test for equality of variances and the second was the T-test for equality of means. For input use, the Levene's test for equality of variances, displayed in Table 5, showed that except for hired labour, the variations in the level of input use were equal within each group and between the two groups as the F-statistics were significant at ($p< 0.05$). The test for equality of means for the various inputs between the two groups, however, showed that there was no significant difference in the estimated means for family and hired labour.

For the socioeconomic variables shown in Table 6, except for experience, which exhibited equal variance within each group and between the two groups, all other socioeconomic 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. Thus, while the null hypothesis holds true for family and hired labour and should be accepted, it does not for the use of other inputs such as farm size, herbicides, seeds and fertilizer and therefore should be rejected for these inputs.

Table 5: Independent sample test for input-use between traditional and improved technology rice farmers in Nigeria

		Levene's test for equality of variances		T-test for equality of means				
		F	Sig.	T	Df	Sig. (2-tailed)	Mean difference	Std. error difference
Farm size	Equal variances assumed	27.331	0.000	12.892	300	.000	3.8655	.2998
Family labour	Equal variances assumed	8.429	0.004	.462	300	.644*	16.4563	35.5900
Hired labour	Equal variances assumed	.494	0.483*	.699	300	.485*	7.6174	10.8915
Herbicide	Equal variances assumed	49.594	0.000	4.335	300	.000	3.6028	.8310
Seed	Equal variances assumed	43.323	0.000	2.022	300	.044	42.0793	20.8110
Fertilizer	Equal variances assumed	179.923	0.000	11.626	300	.000	876.9235	75.4276

* Not significant. Significance level = 5%.
Source: Computed from the field survey data, 2004.

Analysis of the socioeconomic characteristics between the two groups of farmers indicates that there were no significant differences in the estimated means for experience and household size. Hence, hypothesis 2 holds true for them and should be accepted. The hypothesis is rejected for age, education and contact with extension agents, as the result indicated a high level of significant differences for these variables between the two groups. The equality of means in labour input observed between the two groups of farmers may be responsible for the relative equality in the average technical efficiency observed in the frontier analysis, as labour constitutes more than 70% of farm inputs in rice farming in Nigeria.

Table 6: Independent sample test for socioeconomic variables between traditional and improved technologies rice farmers in Nigeria

		Levene's test for equality of variances		T-test for equality of means				
		F	Sig.	T	Df	Sig. (2-tailed)	Mean difference	Std. error difference
Age	Equal variances assumed	1.040	.309*	1.701	300	.090*	1.8747	1.1022
Education	Equal variances assumed	.002	.960*	1.525	300	.128*	.5740	.3763
Contact with EAs	Equal variances assumed	1.024	.312*	1.757	299	.080*	1.1789	.6710
Experience	Equal variances assumed	5.643	.018	6.232	300	.000	7.2077	1.1565
Household size	Equal variances assumed	.164	.685*	4.052	300	.000	2.1194	.5230

* Not significant. Significance level = 5%. EAs = Extension agents.
Source: Computed from field survey data, 2004.

Technology and technical efficiency of the farmers

This section presents the result of the critical analysis of the factors that determine technical efficiency in rice production in Nigeria. The analysis also compares the differential in technical efficiency between the traditional technology and improved technology farmers. Table 7 presents the result of the maximum likelihood estimates for the two groups of farmers, while the distribution of technical efficiency among the farmers is presented in Table 8.

Table 7 indicates that farm size, hired labour, herbicide and seed contributed significantly to the technical efficiency of the farmers. It is obvious from the table that increased output of rice in Nigeria has always been accomplished mainly through area expansion. The coefficients of farm size were 1.07 and 0.88, respectively, for traditional and improved rice variety farmers. This, however, poses some challenges of environmental sustainability of the cultivation method. Although the use of hired labour and herbicides was found to contribute significantly to technical efficiency among the traditional rice variety farmers, their corresponding elasticities did not suggest that increased used of these inputs 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 fertilizer subsidies. As we saw in Table 3, traditional technology farmers used on average 90kg of fertilizer per hectare as against the recommended 200–250kg per hactare. Analysis of the technical efficiency effect model shows that only education and experience have significant effect on the level of technical efficiency. However, all the included variables except experience were correctly signed.

Table 7: 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	0.24	0.05	0.12	0.03	2.05*	1.51
Gamma	0.93	0.83	0.04	0.12	25.68*	6.69*

* Significant. EAs = Extension agents.
Source: Computed from field data, 2004.

For the improved technology rice farmers, only three of the variables, farm size, hired labour and herbicide use, are significant. This indicates that the quality of seed planted was more important than the absolute quantity, and that 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 most critical of these is fertilizer. The result of the inefficiency effects model showed that none of the included variables has significant effects on the technical efficiency of the farmers. Thus, the technical inefficiency of the farmers might have been accounted for by other natural and environmental factors that are not captured in the model. These factors include land quality, weather, labour quality, disease and pest infestations, and so on. Three of the variables, education, contact with extension agent and household size, were correctly signed.

Table 8: 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

Average Technical efficiency = 90.00% (traditional).
Average technical efficiency = 91.00% (improved).
Source: Computed from field data, 2004 .

The frequency distribution of technical efficiency presented in Table 8 shows that about 73% of the traditional rice variety farmers had technical efficiencies above 0.90, against 63% recorded for the improved rice varieties farmers, which indicates that there is very little opportunity to increase technical efficiency among these groups of farmers. In fact, the average technical efficiency of 0.9 shows 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 1.2 tons per hectare, it is obvious that in spite of the high technical efficiency within the context of the country, they are far behind when compared with other countries like Côte d'Ivoire and Senegal, where average yields are over 3.0 tons per hectare. The fact that this result was not significantly different between the two groups calls for technology policy concern about rice production in the country. The following explanation may illuminate 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 actually be improved varieties that have been domesticated for an appreciable length of time. Second, the improved varieties may not possess the required traits for higher yield as compared with those in other countries like Côte 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 a lowland field, the yield may be seriously hampered.

Independent samples test for technical efficiency

The results of the Levene's test for equality of variances displayed in Table 9 indicate that the variation in technical efficiency within each of the groups and between the two groups was not significant. Similarly, the T-test for equality of means between the two groups shows that there was no significant difference between the two means as the T-statistics are not significant at the 5% level. Thus, hypothesis 3, which says that there is no absolute differential in technical efficiency between farmers planting traditional rice varieties and those planting improved varieties in Nigeria, should be accepted.

Table 9: Independent sample test for technical efficiency between traditional and improved technology rice farmers

Levene's test for equality of variances		T-test for equality of means				
F	Sig	T	Df	Sig (2-tailed)	Mean difference	Std. error difference
5.84	0.02	0.28*	300	0.78	0.24	-0.85

* Not significant. Significance level = 5 %.
Source: Computed from field survey data, 2004.

5. Conclusion

Analysis of the socioeconomic characteristics showed that the two groups of Nigerian rice farmers – those who cultivate traditional rice varieties and those who cultivate improved varieties – share relatively the same characteristics except for farming experience and the number of visits by extension agents. As for technical efficiency differentials between the two groups of farmers, the analysis revealed that the majority of both groups of farmers operate on a small and medium scale, cultivating between less than 1 hectare and fewer than 10 hectares.

The results also highlighted the continuous dependence of Nigerian farming on labour input, with the traditional technology rice farmers using more labour than the improved technology farmers. This has serious implications for efficiency, particularly among the improved technology farmers, and may be compounded by the fact that the cost of labour is becoming almost unbearable because of scarcity, on the one hand, and increases in public wages on the other, which tend to draw labour away from the rural areas.

The improved technology rice farmers planted about half the quantity of seed as their traditional counterparts. This may be because a smaller quantity of good quality seed is required per hectare as against the low quality traditional varieties with high incidence of unviable seeds. The study also revealed that although the improved technology rice farmers applied more fertilizer per hectare than the traditional technology group, they both applied less than the recommended amount.

The traditional technology rice farmers applied more herbicides per hectare than their improved technology counterparts. This may be due to the high incidence of weeds in traditional rice variety farms. It is worth noting, however, that most of the pesticides that are used are not produced in the country and therefore the supply is subject to variation. The problem arises when pesticides are not applied on time, which can sometimes lead to high incidence of pests and diseases, and seriously affect the yields.

The result of frontier analysis indicated that farm size was the most significant determinant of technical efficiency. Other variables that contributed to technical efficiency included hired labour, herbicides and seeds. Education and farming experience were found to influence technical efficiency in traditional technology rice farms. Output expansion through extensive cultivation of land has a lot of implications for environmental sustainability. Increased farm wage rate will also affect the use of hired labour. In terms of distribution of technical efficiency among the farmers, the result showed that the distribution was highly skewed in both cases, with over 75% and 60% of the farmers having their technical efficiency above 0.9 in the traditional and improved technology groups, respectively. The average technical efficiency in each case was about 0.9 or 90%. This indicates that in spite of the low yield in each case as compared with their counterparts in other African countries such as Côte d'Ivoire and Senegal, there is little opportunity for increased technical efficiency in either group. This may be a result of the fact that the potential absolute frontier is low among Nigerian rice farmers. Thus, unless something is done to shift the potential absolute frontier, the present efficiency levels of Nigerian rice farmers may be too low to ensure competitiveness.

Finally, the test of hypotheses accepted equality of mean for family and hired labour use but rejected equality of mean for age, education and contact with extension agents. The hypothesis for equality of mean in technical efficiency between the two group was also accepted, which indicated that the improved technology rice farmers are not more technically efficient than their traditional technology counterparts.

Policy implications

The comparatively low scale of rice production may seriously undermine the current policy of government to encourage output expansion through large-scale rice farming. Because labour was identified as a major input in rice production in Nigeria, policy attention should be directed towards providing labour saving technology to ease farm operations. Moreover, the low use of fertilizers may be responsible for the low yields recorded by the improved technology farmers. If the link here is with the supply of the commodity, then low levels of fertilizer application may likely be traced to the scarcity and irregular supply of the product due to government subsidy, which encourages hoarding of the goods. Since fertilizer constitutes the most critical input in rice cultivation, erratic supply and high cost of the input will affect the rice expansion programme. This suggests the need to completely liberalize the procurement and distribution of fertilizer.

Overall, the low level of efficiency and lack of competitiveness of Nigerian rice farmers raises the question of whether decades of improved rice development programmes in Nigeria have produced the much desired or expected upward shift in yield that would be expected from adoption of improved seed varieties.

Suggestions for further study

One major finding emanating from this study is that rice output expansion in Nigeria has been mainly through area expansion, as most of the critical inputs did not significantly influence technical efficiency. The equality in technical efficiency between the two farmer groups requires further investigation into factors influencing technology adoption among Nigerian rice farmers. This kind of study will require a different methodology and analytical approach. It will, however, provide more insight into and useful explanations for the issue of technology diffusion and why some farmers prefer to stick with the traditional seed varieties in spite of lower yields. Such a study will also expose some of the reasons for the non-significant differences in technical efficiency observed between the two groups of farmers, which cannot be adequately provided in this study because of the limitations to the scope of the study.

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