Analysis of the Efficiency and Competitiveness of Rice Production Systems in three Selected States of Northern Nigeria

BY

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DECLARATION

I hereby declare that thisthesis titled '**Analysis oftheEfficiency and Competitiveness of Rice Production Systems in three Selected States of Northern Nigeria**' has been written by me and it is a record of my research work.No part of this work has been presented in any previous application for another degree or diploma at any institution. All borrowed ideas have been duly acknowledged in the text and a list of references provided.

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CERTIFICATION

This thesis titled "**Analysis ofthe Efficiency and Competitiveness of Rice Production Systems in three Selected States of Northern Nigeria"**, by Sani USMAN meets the regulations governing the award of the Degree of Doctor of Philosophy of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation

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DEDICATION

This humblework is dedicated to ever-lasting memory of my mother who left to her heavenly abode on November 14, 2002 (Ramadan 10th,1423).“…….. My Lord! Have mercy on her as she did care for me when I was little”

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ABSTRACT

This study was designed to analyse efficiency and competitiveness of rice production systems in three selected states of Northern Nigeria. A multi stage sampling technique was used to collect primary data from 278 rice farmers in three major rice producing systems in the Northern Nigeria. The data was collected with the aid of pretested questionnaire and analysed usingdescriptive statistics, translog stochastic frontier functions, stochastic metafrontier model, and Policy Analysis Matrix. The secondary data on transportation costs, port charges, storage costs, production subsidy, import tariffs, and exchange rate were obtained from the relevant agencies and publications. The results indicated that over 88% of the farmers were between the active ages of 26 and 55 years. Only 8% of the respondents had no formal education. Land acquisition was mainly (68%) through inheritance while the average farm size was 2.7 hectares. All the three systems of rice production were economically inefficient with mean scores of 0.30, 0.24 and 0.38 for upland, lowland and irrigated system respectively.The years of rice production experience, years of schooling, number of extension visits on rice production practices, years spent as member in farmers' cooperative,and farm size were statistically significant factors that influencedtechnical and allocative inefficiencies. The average scale efficiency was highest for lowland system (0.81) followed by upland (0.80) and the least was irrigated (0.72) system. The mean values for the Technology Gap Ratio for upland, lowland and irrigated systems were 0.446, 0.377 and 0.538 respectively. The private profits of ₦15,796, ₦3,481 and ₦104,831 and social profits of ₦14,019, ₦3,081 and ₦91,387 were obtained for upland, lowland and irrigated systems respectively, indicating that the rice production systems were all competitive and have comparative advantage. The major constraints that hindered rice farmers from achieving their full production potentials were low output prices, high cost of inputs, pests and diseases, inadequate credit facilities and marketing problems. It is recommended among others that farmers' affordability and accessibility to fertilizer, improved rice seeds, extension services and credit facilities should be enhanced for effective achievement of self-sufficiency in rice production and for total import substitution.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Nigeria is the most populous country in Africa accounting for approximately one-sixth of Africa's people (Ojehomon*et al.,* 2009). The country's population in 2006 was 140 million with growth rate of 3.2% and it is predicted to reach 289 million by 2050 (NPC, 2006). The country falls within latitude 10^0North and longitude 8^0East with total land area of 923,768 km^2.It is estimated that about75% (68 million ha) of the total land area has potential for agriculturalactivities with about 33 million ha under cultivation. Similarly, of theestimated 3.14 million ha irrigable land area, only about 534,000 ha (17%)is fully utilized (NISER, 2012).

The highly diversified agro ecological condition of the country makes the production of a wide range of agricultural products possible. Hence, agriculture constitutes one of the most important sectors of the economy.According to Damola (2010), the sector employs about two-thirds of Nigeria's total labour force,contributes about 40% of the Gross Domestic Products (GDP) andprovides 88% of non-oil earnings. The agricultural contribution to GDP byCrops (85%), Livestock (10%), Fisheries (4%) and Forestry (1%), with more than90% of the agricultural output accounted for by small-scale farmerswith approximation of less than two (2) hectares under cropping (Azih, 2008).

The traditional system of agricultural production practice by small-scale farmers still predominates, with its characteristics low technological base, high reliance on manual labour and hence low resource productivity. Manual farm operations impose several limits on farmers' capacity to increase their farm sizes and are technically inefficient and use labour intensive production tools (Oni*et al*., 2009).The food problem in Nigeria has been exacerbated by the low level of productivity of resources used in recent times.Increased output and productivity aredirectly related to improving production efficiency which arises from efficient input usage given the state of technology (Maurice, 2004). The surge in agricultural growth rates experienced in recent years has been powered mainly by expansion in areas planted to staple crops. Productivity has virtually remained unchanged and yields of most crops have actually declined in the past decade (Ojehomon *et al.,* 2009). On the other hand, the domestic demand for rice in particular is growing faster than for any other major staples, with consumption outstripped local production.

Rice is one of the world's most important food crops and serves as a staple food for over 50% of the world's population, especially in India, China, other parts of Asia, and Africa (Daramola, 2005). In Nigeria, rice is a staple in the diets of the majority of people and has become the most rapidly growing food source. Nigeria's rice consumption has increased

significantly over the last decade (6 – 7% per annum) and is now estimated at 6 million metric tonnes annually and the total retail market value for rice in Nigeria is $3.6bn (FMARD, 2012). Furthermore, FMARD (2012) noted that rice has become a staple food of choice in both urban and rural areas accounting for more than 20% of all meals consumed per week by a typical household. Nigeria‘s growing demand for rice is the effect of shifts in consumer preferences driven by urbanization and changes in employment patterns. Rice consumption in Nigeria is forecasted to reach 36 million tonnes by 2050 (FMARD, 2012).

Nigeria‘s growing rice consumption concurrently presents a food security challenge and an economic opportunity for the country. Currently, a third (2 million MT) of Nigeria‘s rice demand is being met by importation, mainly due to low productivity and inefficiency in production systems. According to FMARD (2012), this dependence on importation costs the country $4bn annually, putting immense pressure on the country‘s foreign exchange position. It also exposes the country to the adverse effects of price fluctuations and shocks in the global rice market, an industry which has seen price variability significantly increased in the last three decades. This situation however presents the country with an economic opportunity by improving productivity and efficiency in rice production and substituting rice imports with locally produced rice, massive foreign exchange savings will be gained and over a million jobs can be created across all parts of the country (FMARD, 2012). Additionally, if the natural endowment suitable for commercial rice production in the country are properly harnessed and enabling policy

environment that enhances productivity and efficiency put in place, Nigeria can export rice surplus of 7 to 10 million MT annually to other countries (Daramola, 2005).

One continuing policy and programmes proposal by successive governments in Nigeria has been to reduce the import gap through increasing productivity of farmers and discouraging the imports by putting bans as well as raising the rice tariff. This might lead to increased yields, income of the domestic rice farmers and create additional incentives for growers to add to the acreage under rice and to increase the level of input use and competitiveness.

Some of the policies and programs adopted to achieve self-sufficiency in rice include the Federal Rice Research Station (FRRS), established in 1970 and in 1974 the FRRS changed to the National Cereals Research Institute (NCRI); the River Basin Development Authorities (RBDAs), established in 1977; and Abakaliki Rice Project (ARP), established in 1978 (Imolehin and Wada, 2000; Emodi and Madukwe, 2008). Three of the most recent programmes are the Presidential Initiative on Rice (PIR), established in 1999; the National Program for Food Security (NPFS), the first and second phases were launched in 2001 and 2007 respectively and Agricultural Transformation Agenda (ATA) was launched in 2012.

Despite these policies, projects and programs, domestic rice consumption hascontinued to outpace domestic production leading to an ever-increasing riceimports. This growth is expected to continue steadily due to increasing demand resulting from population growth, increased incomes, urbanization, and the associated expansion of fast food restaurants(Daramola, 2005).

1.2 Problem Statement

Traditionally, important andmajor changes have led to structural increases in rice consumption in the West African sub-region. Since 1973, regional demand has grown at an annual rate of 6%, driven by acombination of population growth and substitution of traditional coarse grains and the consumption of traditional cereals, mainly sorghum and millet, that has fallen by 12kgper capita the share in cereals used as food also dropped from 61% in the early 1970sto 49% in the early 1990swhilethe share of rice in cereals consumed grew from 15% to 26% over the same period (Akpokodje *et al*., 2002). Growth in regional riceconsumption remains high. The FAO projects the annual growth rate to 4.55% beyond theyear 2000. This means that the total volume of rice consumed in West Africa is likely toincrease by 70% over this decade.

In Nigeria, the demand for rice has been increasing ata much faster rate than in any other African country since the mid-1970s (WARDA, 2003).For example, Ogundele and Okoruwa (2006) observed that during the 1960s, Nigeria had the lowest per capita annual consumption ofrice in the sub-region at an annual average of 3kg and since then, Nigerian percapita consumption levels have grown significantly at 7.3% per annum. Consequently,per capita consumption during the 1980s averaged 18kg and then 22kg in the late 1990s. Inan apparent move to respond to the increased per capita consumption of rice in Nigeria,local production boomed, averaging 9.3% per annum (Ogundele and Okoruwa, 2006). However, these increases have been tracedto vast expansion of rice areas and not to increases in productivity, efficiency and competitiveness. On the other hand, the gap between domestic supply and demand continues to increase (FMARD, 2012).

In a bid to address the domestic demand and supply gap, governments have at various times comeup with policies and programmes. It is observed that these policies have not beenconsistent.The fluctuations in policy and the limited capacityof the Nigerian rice sector to match domestic demand have raised serious concerns especially with the abundant natural resources endowment suitable for commercial rice production in the country. The inability of Nigeria to realize self-sufficiency in rice is attributed to low yields due to low resource productivity, inefficiency and inconsistencies in policies in rice economy (Ogundari, 2008; Oni *et al.,* 2009; Oguntade, 2011). Average yield of upland and lowland rainfed rice in Nigeria is 1.8 tonper hectare, while that of the irrigation system is 3.0 ton/ha. This is verylow when compared with 3.0 ton/ha from upland and lowland systems and 7.0 ton/hafrom irrigation systems in places like Côte d'Ivoire and Senegal (Defoer *et al.,* 2004). On the other hand, Ekelem*et al*. (2008) found that if resources are efficiently allocated, about 7.6 tonnes per hectare could be realisedfrom upland/lowland systems and about 11 tonnes per hectare (Defoer *et al.,* 2004) could be obtained from irrigation system, given the current state of technology in Nigeria.

The productivity of farmers can be raised by adoption of improved production technologies or improvement in production efficiency or both(Idiong, 2007).But with the

low rate of adoption of improved technologies by farmers in Nigeria (Saka and Lawal, 2009), improvingfarmers' production efficiency becomes the best alternative to productivity enhancement in the short run.Accordingly, the present Government, as part of its Agricultural Transformation Agenda (ATA), has set a goal to achieve complete sufficiency in rice production by the year 2015. This implies achieving a significant increase in yields of rice to substitute rice import. This target can only be achieved if efficiency at farm-level is improved; resources are used efficiently and deploy more modern rice production resources in the best suited ecology. This, however, requires empirical information on the efficiency and level of competitiveness in rice production and effects of policy intervention on rice production in the three major rice ecologies. Thus, it is against this background that this study was designed to address the following research questions:

i. What are socioeconomic characteristics of rice farmers in the study area?

ii. What are the farm-level technical, allocative, economic and scale efficiencies in rice production?

iii. What are the sources of technical and allocative inefficiencies differentials among rice farmers?

iv. What are the technology gap ratios among the major rice producing systems?

v. How competitive is rice production in these systems?

vi. What are the constraints to rice production in the study area?

1.3 Objectives of the Study

The broad objective of the study was to analyse production efficiency and competitiveness of rice production systems in threeselected states of Northern Nigeria. The specific objectives were to:

i. describe the socioeconomic characteristics of rice farmers in the study area,

ii. estimate the farm-level technical, allocative, economic and scale efficiencies in rice production,

iii. ascertain the sources of technical and allocative inefficiencies differentials among rice farmers,

iv. determine the technology gap ratios among the major rice producing systems,

v. determine the level of competitiveness of rice production in the three major rice systems, and

vi. describe the constraints to rice production in the study area.

1.4 Justification for the Study

In spite of the strategic importance of rice to Nigeria and to the West African sub-region, comprehensive and up-to-date information about the production efficiencies and competitiveness of the rice production systems across the major rice production ecologies is inadequate. The few available studies were either system based (e.g. Awotide, 2004; Idiong, 2007) or location specific (e.g. Ogundele, 2003; Shehu and Mshella, 2007) or carried out separately (e.g.Daramola, 2005; Oguntade, 2011; Liverpool *et al.*, 2009). Furthermore, most of the studies focused basically on the profitability of the enterprise(e.g. Inuwa *et al*., 2011; Ohajianya and Onyenweaku, 2003), without in-depth exploration of the efficiencies of farmers across the major rice ecologies and also the level of competitiveness.

Most of the past studies that assessed efficiency and competitiveness focus either on single ecology (e.g. Kebbeh *et al.*, 2003) or on homogeneous farms (e.g. Okoruwa *et al.*, 2009) without considering technology differences across farms within the industry. Critics have flawed such measures on the basis that they fail to deal appropriately with the peculiarity of the different ecologies and varying production systems. It is noted that Nigerian rice sector is a complex one thus, while most studies provide only an assessment of a particular ecology, the production in Nigeria is found to be very diverse and dynamic. Consequently, it will be very difficult to obtain a comprehensive overview from such studies and as observed by NISER (2012) that past policies that were based on findings of such studies have not produced desired results.

A few studies conducted separately in the past have already demonstrated that Nigeria has room for improving productivity through efficiency enhancement (Awotide, 2004; Okoruwa*et al.*, 2005; Ayinde *et al.*, 2009) and comparative advantage in the production of rice (Funmilayo, 2006; Liverpool*et al*., 2009;Oguntade, 2011).Consequently, updated information on factors influencing efficiencies and competitiveness should be used jointly as guiding tools for informed decision making in order to transform rice industry and trade in the country.

The present and prospective rice farmers will surely find the results of this study useful as it will provide rice ecology-specific information on inputs that affect rice production. Also,it hopes to contribute to the body of knowledge and serves as a baseline for further research work.

1.5 Hypotheses for the Study

The tested hypotheses in this study are that: -

1. rice farmers arenot operating on the technical efficient frontier ($\gamma \neq 0$),
2. socioeconomic characteristics of rice farmers have no effect on the technical efficiency ($U_i = 0$),
3. the stochastic production frontiers for all the rice production systems are the same,
4. the study areas have no comparative advantage in rice production,

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Agriculture and the Nigerian Economy

Globally, agricultural production is crucial to the overall wellbeing of the populace, especially in developing countries. This necessitates different countries to give high priority to agriculture and struggle to develop and sustain the sector, thereby ensuring sustainable food security, employment opportunities, and foreign exchange earnings amongst others. However, in Nigeria, where over 70% of the population, mostly rural dwellers, is involved in agricultural activities, yet accounting for less than 7% of the

foreign exchange earnings, the sector remains largely traditional, subsistent and undeveloped. The Nigerian agricultural sector is dominated mostly by smallholder producers, who operate farm lands of no more than two (2)hectares accounting for over 90%of agricultural outputs (Azih, 2008). The food crops dominate production and the major food crops are rice, sorghum, millet, maize, cassava and yam. These are produced in less than 50% of the 79 million hectares of available arable land area (Manyong *et al.*, 2005).

The sudden increase in agricultural growth rates experienced has been attributed mainly by expansion in areas planted to staple crops. Productivity has remained flat and yields of most crops are actually declining (Oni *et al.*,2009). Public intervention and investments under the National Food Security Programme and Agricultural Transformation Agenda were aimed at sparking off a sustainable Green Revolution in the country.As it has been observed, Nigeria may not be able to meet its food production and poverty reduction goals without a significant and sustainable production increase in the agricultural sector.Furthermore, the global food crisis of early 2008 has not removed Nigeria from the unpredictable shortages of global food and price spirals of the period thus worsening Nigeria's ability of making food available and accessible at affordable prices to the teeming consumers. Reliance on food imports to supplement local production and demand remains the only option unless the sector is given more attention and enabling policy environment to improve farmers' productivity and efficiency. As common to traditional agriculture, the returns to farmers are not attractivedue to high cost of production and low productivity. According Ojehomon *et al.* (2009), the only way out to achieving self-sufficiency in Nigeria is to have a policy mix that will embraces institutional restructuring, strategic investments and coordinated efforts at all levels to empower farmers and provide improved conditions in rural areas. Such efforts would focus on rehabilitating degraded rural infrastructure, adopting productivity and efficiency enhancing measures and taking steps to stimulate competitiveness.

2.2 The Rice Economy and Policies in Nigeria

Over the last three decades, the rice crop has seen consistent increases in demand and has assumed strategic importance in Nigeria's food security plans and programs. The increase in demand for rice in Nigeria is attributed to increase in population, rapid urbanization and rising incomes. This surge in rice demand has triggered an increase in domestic rice production in which more lands were put under rice cultivation. However, demand still exceeds production and large quantities of rice are imported to meet domestic demand at a huge cost in foreign currency. Nigeria consumes a total of 6 million tonnes of milled

rice annually of which approximately 2 million tonnes (33.3%) is imported. Nigeria is therefore a key player in the international rice market, and is the world‘s second largest importer accounting for roughly 6% of the global rice trade per annum. Growth forecasts indicate that the average growth of rice consumption in Nigeria is now more than 7% per year and total demand is forecasted to reach 9 million MT by 2016 (FMARD, 2012).

To reverse the trend, Nigerianhad employed various trade policy instruments such as tariff, import restrictions, and outright ban on rice import in the last three decadeswith the goal of encouraging local production to address the widening demand-supply gapand making Nigeria more self-sufficient in rice.The consequences of huge importation of productin any country at relatively cheap prices erode the competitiveness of domestic product and serves as a major disincentive to producers of such product.

Among such protective policies implemented in Nigeria was Structural Adjustment Programme (SAP) which was introduced in 1986. It wasmainly implemented as policy instrument to ban food importation, especially rice. Consequently the index of bias in protection shifted in favour of rice and rice farmers responded to this policy by way of increased production. The ban was, nevertheless, poorly implemented by the government as shown by the presence of such commodity in major market places during this ban period. The ban on rice importation remained in effect till 1995 when it was lifted in line with the World Trade Organization agreement on trade liberalization. Since the ban was lifted, government has resorted to the use of tariff measures to regulate influx of the commodity. Over time the tariff on rice has increased from an average of 50% during the 1996-1999 period to 100% in 2002 and 150% in 2003. In 2009 the tariff was adjusted down to 30% (which consists of 20% tariffs and 10% tax) for milled rice and 10% tariffs for brown rice in line with the ECOWAS agreement on unified tariffs on tradable commodities.

2.3 Rice Production Ecology

The three main rice systems in West Africa are: (i) Rainfed upland; (ii) Rainfed lowland – i.e. without water control; and (iii) Irrigated – i.e. lowland with water control (Erenstein *et al.,* 2003). In Nigeria, rice grows in all the agroecological zones as diverse as the Sahel of Borno state and the coastal swamps of the southwest and south-south. Rice production in Nigeria is predominantly rainfed, with an emphasis on lowlands. Longtau (2003)

identified six rice growing environment in Nigeria. These are: Upland, Rain-fed Lowland, Irrigated Lowland, Deep Inland Water, Hydromorphic and Mangrove Swamp. He stressed that irrigation, lowland and upland are the predominant rice systems in the country with Kaduna state presents the most balanced division between the upland and lowland systems. The summary of rice ecology in Nigeria is presented in Table 2.1.

Table 2.1. Summary of rice production systems

Production system	**Characteristics**	**Geographic spread**
Upland	Rainfed rice grown on free-draining fertile soils. This is also called dry uplands.	Widespread, except coasts, high rain forests and Sahel.
Lowland	Rainfed or irrigated rice in aquatic conditions or medium ground water table. Water covers the soilcompletely at some stage during the croppingseason. These are called shallow swamps orfadama	Very widespread from high rain forest to Sahel.
Hydromorphic	Rainfed rice grown on soils with shallow ground water table or an impermeable layer. This is also called wet uplands.	Very widespread at the fringes of streams and intermediate zone between upland and swamps of rivers in the Savannah.
Deep inland water	Rainfed rice grown on soils with deep water tables. The rice crop floats at some stage and harvesting may be done from a canoe. These are also called deep fadamas or floodplains	Found in the Sokoto-Rima Basin and Chad Basin, floodplains of the Niger, Benue, Kaduna, Gbako,Hadejia and Komadugu-Yobe.
Mangrove Swamps	Rice grown at the coast or swamps of the high rain forest.	Coastal areas and Warri area in Delta state.

Source: Longtau (2003)

2.4 Analytical Models for Efficiency and Competitiveness Measurements

2.4.1 Production efficiency and its components

In every country, enhancing productivity and efficiency in agricultural sector remains a vital key to improving the standard and quality of life, especially in developing countries where a preponderant majority of the poor are employed. One strategy to improving farm productivity is the adoption of new technologies. The adoption of new technologies, as a

means of accelerating economic development, has been the focus of a number of researchers and policymakers. Awotide *et al*. (2010), Kudi *et al*. (2011) and Dontsop *et al.* (2011)focused particularly on the role of new technologies in fostering productivity and development. But technological progress is not the only parameter that determines output growth, enhancement in efficiency can also affect growth in output.

Perhaps the most important work in the production efficiency literature is that of Farrell (1957) who drew upon the work of Debreu (1951) and Koopmans (1951). This research laid the foundation for the development of a number of related efficiency models, collectively known as *frontier* models.

There are two main benefits that result from estimating frontier functions, as compared to estimating average functions using *ordinary least squares* (OLS) technique. First, when a frontier function is estimated, the result is strongly influenced by the best performing firm, and therefore the frontier reflects the technology set that the most efficient firm uses. Compare this to the estimation of an average function, which only shows the technology set employed by an average firm. Second, frontier functions provide a useful performance benchmark. These functions normally represent best practice technology, against which the efficiency of other firms within the industry can be measured. It is for this reason that frontier estimation continues to attract attention in the empirical production economics literature.

In microeconomic theory of the firm, production (or economic) efficiency is decomposed into technical and allocative efficiency. A producer is said to be technically efficient if production occurs on the boundary of the producer's possibilities set, and technically inefficient if production occurs on the interior of the production possibilities set. That is, technical efficiency is the extent to which maximum possible output is achieved from a given combination of inputs (Haghiri, 2003). On the other hand, a producer is said to be allocatively efficient if production occurs in a region of the production possibilities set that satisfies the producer's behavioural objective.

Farell (1957) distinguished between technical and allocative efficiency in production through the use of a frontier production function. Technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under certain technology. Allocative efficiency refers to the ability of using inputs in optimal proportions for given factor prices (i.e. where the ratio of marginal products for each pair of inputs is equal to the ratio of market prices). The product of technical and allocative efficiency is the Economic efficiency. An economically efficient input-output combination would be on both the frontier function and expansion path. Alternatively, economic efficiency can be defined as the ability of a production organization or any other entity to produce a given output at minimum cost. If a firm has achieved both technically and allocatively efficient levels of production, it is economically efficient and new investment streams may be critical for any new development.

2.4.1.1*Approaches to production efficiency measurement*

The measurement of production efficiency has been highly recognized as an important exercise in view of its relevance for policy makers in showing whether it is possible to increase output by simply increasing the efficiency of the firm without substantial additional resources. The methodologies for examining the production efficiency of farmers can generally be grouped into four different broad categories: the average factor productivity estimates; the linear programming approach; the production function approach; and the profit function methodology. The simplest measure of efficiency is the partial or average productivity index. This approach is an unsatisfactory measure since it ignores the presence of other factors, which affect average or marginal productivity and consider only one input at a time.

The conventional production function approach is the most widely used measure in the analysis of production efficiency of farmers. The traditional approach is to estimate an average production function by a statistical technique such as least squares. Average production functions have received far more attention for the simple statistical reason that the mean of the error terms is zero. This is, however, not consistent with the definition of the production function.

Thus, finding a measure of technical efficiency that is consistent with the definition of production function has been a major concern for many researchers. The production technology is represented by the transformation (production) function that defines the maximum attainable outputs from different combinations of inputs. Alternately, if considered from an input orientation side, it describes the minimum amount of inputs required to achieve a given output level. In other words, the production function describes a boundary or a frontier (Coelli *et al.,* 2005).

Given the definition of a production function, interest has then centered more on specifying and locating the production frontier. Alternative production models have often been proposed and the frontier model is one of these models and there seems to be a consensus in the recent literature on production function estimation that the production frontier rather than the average production function corresponds to the theoretical notions of the production function. Farrell (1957) had been the pioneer who introduced the frontier measure of efficiency, which reflects actual firm performances, and can include all relevant factors of production. The production frontier has to be empirically constructed from observed data in order to compare the position of a firm or a farm relative to the frontier. Several methods have been developed for the empirical measurement of frontier models.

The different methods that are developed to estimate the frontier production function can be categorized based on certain major criteria (Haghiri, 2003). First, based on the way the frontier is specified, the frontier may be specified as a parametric function or as a non-parametric function. Second, based on the way the frontier is estimated, the frontier may be estimated either through programming techniques or through the explicit use of statistical procedures. Third, based on the way the deviations from the frontier are

interpreted, deviations may be interpreted simply as inefficiencies or they could be treated as mixtures of inefficiency and statistical noise, simply called deterministic and stochastic frontiers respectively.

Deterministic Frontier:

i. Parametric Programming

Farrell (1957) proposed computing a parametric convex hull of the observed input-output ratios. For this purpose, he recommended the Cobb-Douglas production function. Although Farrell acknowledged the undesirability of imposing a specific and restricted functional form on the frontier, he noted the advantage of being able to express the frontier in a mathematical form.

Aigner and Chu (1968) were the first to follow Farrell's suggestion. They specified a homogenous Cobb-Douglas production frontier, and required all observations to be on or beneath the frontier. Their model may be written as

$$lnY_i = lnf(X_i;\beta) - u_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.1)$$

Where Y_i is the output of the i^{th} firm, X_i is the input of i^{th}firm and u_i is a one-sided disturbance term. The one-sided error term forces $Y \leq f(X)$. The parameter vector β may be estimated either by linear programming (i.e., minimizing the sum of the absolute values of the residuals, subject to the constraint that each residual be non-positive) or by quadratic programming (i.e., minimizing the sum of squared residuals, subject to the same constraint). They suggested that minimization of the sum of absolute deviations, $\sum_{i=1}^{n}\{Y_i - f(X_i;\beta)\}$ subject to $Y \leq f(X,;\beta)$, which is a linear programming problem if $f(Xi;\beta)$ is linear in β. This is corresponding to minimization of the one-sided error term, ui.Instead, they recommended minimization of the sum of squared deviations, $\sum_{i=1}^{n}\{Y_i - f(X_i;\beta)\}^2$, subject to the same constraint, which is a quadratic programming problem if $f(Xi;\beta)$ is linear in β. Although, the technical efficiency of each observation can be computed directly from the vector of residuals, since uiaccounts for technical inefficiency but Aigner and Chu (1968) did not use this method.

The main advantage of the parametric deterministic approach in relation to the non-parametric approach is the ability to describe frontier technology in a simple mathematical model. However, the mathematical model may be too simple. The parametric approach imposes a structure on the frontier that may be unwarranted. The parametric approach often imposes limitations on the number of observations that can be technically efficient. In the homogenous Cobb-Douglas case, for example, when the linear programming algorithm is used, there will, in general, be only as many technically efficient observations as there are parameters to be estimated. As was the case with the non-parametric frontier, the estimated frontier is supported by a subset of the data and is therefore extremely sensitive to outliers. One possibility given by Aigner and Chu (1968)

and applied by Timmer (1971) was essential just to discard a few observations. This has led to the development of the so-called probabilistic frontiers.

Similarly, another problem associated with this method is that the estimates which it produces have no statistical properties. That is, mathematical programming procedures produce estimates without standard errors, *t*-ratios, and so forth. Basically this is because no assumptions are made about the explanatory variables or the disturbance term in equation (2.1) and without some statistical assumptions inferential results cannot beacquired.

ii. Non-parametric Programming

Farrell's (1957) original work formed the basis of the non-parametric programming method with subsequent extensions of his work by Charnes *et al*. (1978) and Fare *et al*. (1985) giving rise to what is often referred to as Data Envelopment Analysis (DEA). In this approach, technical efficiency is defined as the minimum input for any particular combination of outputs. Farrell's original approach of computing the efficiency frontier as a convex hull in the input coefficient space was generalized to multiple outputs. This was reformulated into calculating the individual input saving efficiency measures by solving a linear programming (LP) problem for each unit by Charnes *et al*. (1978) under the constant returns to scale assumption. Fare *et al.* (1985) and Banker *et al*. (1984) extended this approach to the case of variable returns to scale and developed corresponding efficiency measures.

Fare *et al.*(1994) stated that DEA is a nonparametric approach to distance estimation and the method involves the use of linear programming to construct a piecewise linear envelopment frontier over the data point such that all observed points lie on or below the production frontier. Let X be a *K*x*N* matrix of inputs, which is constructed by placing the input vectors, x, of all *N* firms side by side, and *Y* denotes the *M*x *N* output matrix which is formed in an analogous manner.

The output oriented variable returns to scale DEA frontier is expressed by the solution to *N* linear programs of the form:

$$\min_{\theta\lambda} \theta$$

Subject to

$$-y_I/\theta + Y\lambda \geq 0$$
$$x_I + X\lambda \geq 0$$
$$N1'\lambda = 1$$
$$\lambda \geq 0, \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

where*N*1 is an *N*x1 vector of 1s, λ is an *N*x 1 vector of weights, and θ is the ouptu distance measure. We note that $0 \leq \theta \geq 1$ and that $1/\theta$ is the proportional expansion in outputs that could be achieved the ith firm, with input quantities held constant.

In a similar manner, the input-orientated returns to scale DEA frontier is defined by the solution to *N* linear programs of the form

$$\min_{\theta\lambda} p$$

Subject to
$$-y_I + Y\lambda \geq 0$$
$$x_I/p - X\lambda \geq 0$$
$$N1'\lambda = 1$$
$$\lambda \geq 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

where p is the input distance measure. We note that $1 \leq p \leq \infty$ and that 1/p is the proportional reduction in inputs that could be achieved by the *i*th firm, with output quantities held constant.

The technical efficiency measure under constant returns to scale, also called the 'overall' technical efficiency measure, is obtained by solving *N* linear programs of the form:

$$\min_{\theta_i^{CRS}} \theta_i^{CRS}$$

Subject to
$$-Y\lambda + y_i \leq 0$$
$$\theta_i^{CRS} x_i - X\lambda \geq 0$$
$$\lambda \geq 0, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.4)$$

where θ_i^{CRS} is a technical efficiency measure of the ith firm under constant returns to scale and $0 \leq \theta \leq 1$. The output and input oriented models will estimate exactly the same frontier surface and, therefore, by definition, identify the same set of firm as being efficient. The efficiency measures may, however, differ between the input and output orientations. Under the assumption of constant returns to scale, the estimated frontier and the efficiency measures remain unchanged by the choice of orientation (Coelli*et al.*, 20005).

Farrell (1957) used an input-oriented approach to illustrate the measurement of efficiency. He adopted a simple example involving firms which use two inputs, X_1 and X_2 to produce a single output Y, under the assumption of constant returns to scale. The constant return to scale assumption allows representing the technology using a unit isoquant. Figure 1reveals how to obtain the technical, allocative, and economic efficiency. In this figure, SS' represents an isoquant drawn in an input-input space and adjusted by the unit of output. Assuming point P as the quantity of input that a firm uses to produce a unit of output, the firm's technical efficiency is obtained by the ratio of OQ/OP. Given the information on input prices, shown by the isocost line AA', the allocative efficiency or price efficiency can be computed by the ratio of OR/OQ. Thus, the ratio of OR/OP yields the economic efficiency of the firm.

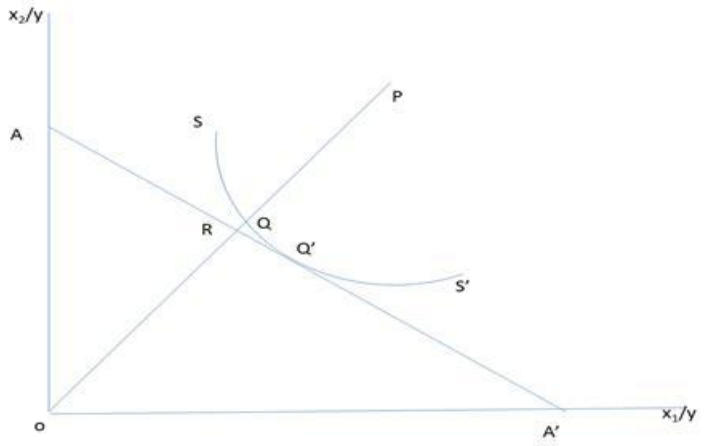


Figure 1: Farrell's Measure of Technical and Allocative Efficiencies
Source: Adapted from Kumbhakar and Lovell (2000)

On the whole, the main advantage of the non-parametric approach to technical efficiency measurement is that no functional form is imposed on the data. The main disadvantage is that the frontier is computed from a supporting subset of observations from the sample and is therefore particularly susceptible to extreme observations and measurement errors. A second disadvantage of the approach is that the process of resource allocation to achieve better output is never explicitly used in the model. A third disadvantage of the approach is that estimated functions have no statistical properties, and hence the estimated production frontier has no statistical properties to be evaluated upon.

iii. Corrected Ordinary Least Squares (COLS)

In his discussion of Farell's original paper, Winston (1957) suggested that the deterministic production frontier model (2.1) could be estimated in two steps. In the first step ordinary least squares (OLS) is used to obtain consistent and unbiased estimates of the slope of parameters and a consistent but biased estimate of the intercept parameter. In the second step the biased OLS intercept β_0 is shifted up ("corrected") to ensure that the estimated frontier bounds the data from above. The COLS intercept is estimated consistently by

$$\hat{\beta}_0^* = \hat{\beta}_0 + \max\{\hat{u}_i\} \dots\dots\dots\dots\dots\dots (2.5)$$

where the $\hat{u}_i$ are the OLS residuals. The OLS residuals are corrected in the opposite direction, and so

$$-\hat{u}_i^* = \hat{u}_i - max\{\hat{u}_i\} \dots\dots\dots\dots\dots\dots\dots (2.6)$$

The COLS residuals $\hat{u}_i^*$ are nonnegative, with at least one being zero, and can be used to provide consistent estimates of the technical efficiency of each producer by means of $TE_i = exp\{-\hat{u}_i^*\}$.

According to Kumbhakar and Lovell (2000), the COLS technique is easy to implement, and generates an estimated production frontier that lies on {for at least one producer, by virtue of equation (2.6)} or above the data. However, this simplicity comes at a cost: The estimated production frontier is pararell (in natural logarithms of the variables) to the OLS regression, since only the OLS intercept is corrected. This implies that the structure of "best practice" production technology is the same as structure of the "central tendency" production technology. This is an undesirably restrictive property of the COLS procedure, since the structure of best practice production technology ought to be permitted to differ from that of production technology down in the middle of the data, where producers are less efficient than the best practice producers.

iv. Modified Ordinary Least Squares (MOLS)

Afriat (1972) proposed an interesting variation on COLS. They suggested that the deterministic production frontier model (2.1) could be estimated by OLS under the assumption that the disturbances follow an explicit one-sided distribution, such as exponential or half normal. A motivation for such an assumption is that technical efficiency might reasonably be expected to follow one of those distributions with increasing degrees of technical inefficiency being increasingly less likely. The MOLS procedure is very similar to the two-step COLS procedure. After estimation by OLS, the estimated intercept is shifted up ("modified") by the means of the assumed one-sided distribution. In the case equations (2.5) and (2.6) become

$$\hat{\beta}_0^{**} = \hat{\beta}_0 + \mathrm{E}(\hat{u}_i) \dots\dots\dots\dots\dots\dots (2.7)$$

and

$$-\hat{u}_i^{**} = \hat{u}_i - E\{\hat{u}_i\} \dots\dots\dots\dots\dots\dots\dots (2.8)$$

respectively. The OLS residuals can then be used to provide consistent estimates of the technical efficiency of each producer, exactly as in the COLS model.

The MOLS procedure is also easy to implement. However, there is no guarantee that the modification of OLS shifts the estimated intercept up by enough to ensure that all producers are bounded from above by the estimated production frontier. Since if a producer has a sufficiently large positive OLS residual it is possible that $\{\hat{u}_i - E\{\hat{u}_i\}\} > 0$ for that producer. If this happens, one is left in the uncomfortable position of having to explain a technical efficiency score greater than unity (Kumbhakar and Lovell, 2000). It is also possible that MOLS shifts the estimated intercept so far up that no producer is technically efficient, although this is a much less uncomfortable outcome to explain.

The Stochastic Frontier Production Function:

The stochastic frontier production model represents an improvement over the traditional average production function and over the deterministic functions, which use mathematical programming to construct production frontiers. The notion of a deterministic frontier shared by all firms ignores the possibility that a firm's performance may be affected by factors entirely outside its control such as bad weather and input supply breakdowns as well as by factors under its control (i.e., technical inefficiency). To lump up the effects of exogenous shocks, both favorable and unfavorable, together with the effects of measurement errors and inefficiency into a single one-sided error term, and to label the mixture inefficiency is a problem with the deterministic frontiers.

To solve this problem associated with the deterministic frontiers, stochastic production frontier was developed. Aigner *et al.* (1977) and Meeusen and Broeck (1977) simultaneously introduced stochastic production frontier models. The econometric approach to estimate frontier models uses a parametricrepresentation of technology along with a two-part composed error term.Under the assumption that f(xi;β) is of Cobb-Douglas type, the stochastic frontier model in equation (2.1) can be written in logs as:

$$lnY_i = \beta_0 + \sum_n \beta_i lnx_{ni} + \varepsilon_i \dots\dots\dots\dots\dots\dots\dots (2.9)$$

where $\varepsilon_i$is an error term with

$$\varepsilon_i = v_i - u_i$$
$$i = 1, 2, 3, \dots\dots\dots n$$

The economic logic behind this specification equation (2.9) is that the production process issubject to two economically distinguishable random disturbances: statisticalnoise represented by $v_i$and technical inefficiency represented byu_i. There aresome assumptions necessary on the characteristics of these components. Theerrors $v_i$are assumed to have a symmetric distribution; in particular, theyare independently and identically distribute as $N(0, \sigma_u^2)$. The component$u_i$is assumed to be distributed independently of $v_i$and to satisfy$u_i \geq 0$(e.g. It followsaone-sidednormaldistribution $N^+(0, \sigma_u^2)$. The non-negativity ofthe technical inefficiency term reflects the fact that if $u_i > 0$ the countrywill not produce at the maximum attainable level. Any deviation below thefrontier is the result of factors partly under the production unit's control,but the frontier itself can randomly vary across firms or over time for thesame production unit. This last consideration allows the assertion that thefrontier is stochastic, with a random disturbance $v_i$being positive or negativedepending on favourable or unfavourable external events.Conventionally, the efficiency term can take the form of a truncated normaldistribution, of a half-normal distribution, of an exponential distribution,or of a gamma distribution.

Metafrontier Technique:

In the last decade, a new approach of accounting for technology variations in both crosssection and panel data through metafrontier estimation has been developed in two formats:DEA-metafrontier and stochastic metafrontier. The DEA-metafrontier method can beconsidered as a 'double mathematical programming' approach since it involves LP analysis inthe first stage, followed with either a quadratic programming (QP) or another LP equation tooptimise parameters obtained from the first estimation stage. This approach has been appliedin a few studies (e.g., Ayinde*et al*., 2009; Villano *et al.*, 2010; Otieno *et al.,* 2011). In order to capture variations in technology within and between production systems, Batteseand Rao (2002) proposed the use of a stochastic metafrontier production function to measureefficiency and technology gaps of firms producing in different technological environments.This approach is implicitly underpinned by two distinct data-generating mechanisms; one thatexplains deviations between observed outputs and group frontiers, and another that explainsdeviations between observed outputs and the metafrontier. However, the above method islimited because some points on the estimated metafrontier may lie below points on theestimated group frontiers. In order to address this limitation, Battese *et al*. (2004) defined themetafrontier as a smooth function that envelops the explained (deterministic) components ofthe group stochastic frontier functions.

Thus, the metafrontier function captures the highest possible output level (y) attainable, giventhe input (x) and common technology in the industry (Figure 2). Output levels for producerswho are efficient both in respective group frontiers (e.g., frontier 1) and in the entire industrylie on the metafrontier. Frontiers 2 and 3 fall below the metafrontier; this implies that theyrepresent efficient production in the groups/production systems, but not so for the industry.

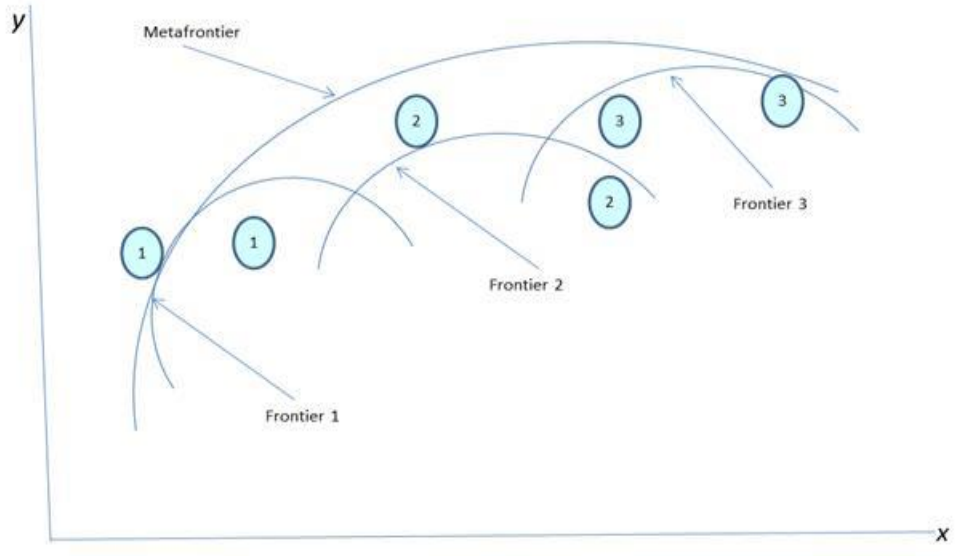


Figure 2: Metafrontier Function Model
Source: Battese *et al.* (2004).

i. Stochastic Metafrontier Technique

The original model ofequation(2.9)concurrently developed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) has been extended and modified to accommodate different circumstances. One of the most recent extensions of the original model is the estimation of technical inefficiencies to accommodate differences in technologies across firms in the industry. The stochastic metafrontier framework provides a measure of the technology gap.

The model expressed in equation(2.10) allows comparison of farms operating with similar technologies. However,farms in different production systems do not always have access to the sametechnology. Accordingly, Tsionas (2002) point out that an assumptionof similar technologies across farms when actually they differ result inerroneous measurement of efficiency by mixing technological differences with technology-specificinefficiency. Technologies in his study comprised the type of ecology-specific rice variety,sources of labour, farm machinery and farm operations. Variations in output among production systems due to technologydifferences can be captured by using the metafrontier, which is considered to be a smooth orcommon technology frontier that envelops the deterministic components of the group stochasticfrontiers (Battese and Rao, 2002; Battese *et al*., 2004). The metafrontier explains deviationsbetween observed outputs and the maximum possible explained output levels in the group frontiers.Following O'Donnell *et al*. (2008), the stochastic metafrontier equation can be expressed as:

$$Y_n^* = f(X_n, \beta^*) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.10)$$

$$n = 1, 2, \ldots\ldots n$$

where $f(X_n, \beta^*)$is a specified functional form; $Y_n^*$is the metafrontier output; and β^*denotes the vector of metafrontier parameters that satisfy the constraints:

$$f(X_n, \beta^*) \geq f(X_n, \beta_k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.11)$$

$$for\ all\ k = 1, 2, \ldots\ldots K$$

According to equation (2.11), the metafrontier function dominates all the group frontiers. In order tosatisfy this condition, an optimization problem is solved, where the sum of absolute deviations (orsum of squared deviations) of the metafrontier values from the group frontiers is minimised. Theoptimization problem is usually expressed as (Battese *et al*., 2004):

$$\min \sum_{n=1}^{N} [lnf(X_n, \beta^*) - lnf(X_n, \beta_k)]$$

Subject to:

$$lnf(X_n, \beta^*) \geq f(X_n, \beta_k) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.12)$$

In terms of the metafrontier, the observed output for the *nth* farm in the *kth* production system {measured by the stochastic frontier in the equation (2.11)} can be expressed as:

$$Y_{nk}^* = \exp(-u_{nk}).\frac{f(X_n, \beta_k)}{f(X_n, \beta^*)} . f(X_n, \beta^*) exp(V_{nk}) \ldots\ldots\ldots\ldots\ldots\ldots (2.12)$$

Note that from equation (2.12) TE_{nk}= exp(-u_{nk}) and the middle segment in equation (2.12) represents thetechnology gapratio (TGR), whose value is bounded between zero and one and is expressed as:

$$TGR_n = \frac{f(X_n, \beta_k)}{f(X_n, \beta^*)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.13)$$

The TGR measures the ratio of the output for the frontier production function for the *kth*group or production system relative to the potential output defined by the metafrontier, given theobserved inputs (Battese and Rao, 2002; Battese *et al.,* 2004). Values of TGR closer to 1 imply thata farm in a given production system is producing nearer to the maximum potential output given thetechnology available for the whole industry. The notion of TGR defined in equation (2.13)indicates the gap between the production frontier for aparticular production system or group frontier and the metafrontier (Battese *et al*., 2004).

The TE of the *nth* farm relative to the metafrontier (TE_n^*) is the ratio of the observed outputfor the *nth* farm relative to the metafrontier output, adjusted for the corresponding random error suchthat:

$$TE_n^* = \frac{Y_{nk}}{f(X_n, \beta^*) exp(V_{nk})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.14)$$

Following equations(2.12), (2.13) and (2.14), the TE_n^*can be expressed as the product of the TE relative to thestochastic frontier of a given production system and the TGR:

$$TE_n^* = TE_{nk} * TGR_n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.15)$$

2.4.2Definition and measures of competitiveness

The most important question that emphasizes research in economics is how to allocate scarce productive resources in order to ensure social welfare, including full employment and high living standards. Researchers are interested in which sector can contribute the most to a nation's economic growth and they often turn to the concept of competitiveness as a basis for analysis. The European Commission (EC) defined competitiveness as a

sustained raise in the standards of living of a nation or region (i.e. like in agricultural sector of nation or region) and as low a level of involuntary unemployment as possible (EC, 2009).

Latruffe (2010) defined competitiveness as the ability to face competition and to be successful when facing competition. Competitiveness would then be the ability to sell products that meet demand requirements (price, quality, quantity) and, at the same time, ensure profits over time that enable the firm to thrive. Competition may be within domestic markets (in which case firms, or sectors, in the same country are compared with each other) or international (in this case, comparisons are made between countries). Latruffe (2010) stress that the measurement of competitiveness can be made according to two disciplines: i) the neoclassical economics which focuses on trade success and which measures competitiveness with the real exchange rate, comparative advantage indices, and export or import indices; and ii) the strategic management school places which places emphasis on the firm's structure and strategy. In the latter, competitiveness is defined as cost leadership and non-price supremacy, with cost competitiveness measured according to various cost indicators, as well as productivity and efficiency.

2.4.2.1*Trade measures of competitiveness*

Trade theory suggests that nation's competitiveness is based on the concept of comparative advantage. Comparative advantage postulates that trade flows are the result of differences in production costs among countries and that a country will specialise in the production of a good in which it has a cost advantage. Such a concept is useful when comparing countries, that is to say when measuring international competitiveness.

The real exchange rate is a measure of international competitiveness. It explains that where the demand for the currency of a competitive country is high, this strengthens the currency's exchange rate. The comparative advantagecalculates the ratio of a country's export share of a commodity in the international market to the country's export share of all other commodities.

The export market shares (EMS) are a simple measure of competitiveness. EMS can be measured in terms of quantity or in terms of value. The net export index is the country's or sector's exports less its imports divided by the total value of trade.

2.4.2.2*Strategic management measures of competitiveness*

Porter (1990) was one of the first to underline the importance of firms' strategy and structure in developing their competitiveness. The author proposed the so-called "diamond model" according to which nations succeed in industries for which the national diamond is the most favourable. The four corners of the diamond are: i) factor conditions; ii) demand conditions; iii) presence of related and supporting industries; and, iv) firm strategy, structure and rivalry. In this framework, competitiveness is revealed by performance indicators such as cost superiority, profitability, productivity, and efficiency.

In the cost measures, the domestic resource costs (DRC) ratio compares the opportunity costs of domestic production with the value added it generates (Gorton *et al.,* 2001). In other words, it compares the value of the non-tradable domestic resources used to produce one unit of the good with what the good would earn if it was exported (Liefert, 2002). It was originally proposed for measuring the gain from expanding profitable projects or the cost of maintaining unprofitable activities through trade protection.

The Social Cost-Benefit (SCB)ratio: According to Masters and Winter-Nelson (1995) because the DRC ratio is based on the cost of non-tradable inputs, it understates the competitiveness of activities that use mainly such domestic factors in comparison to those that rely more on tradable inputs. To overcome this shortcoming, the authors propose the social cost-benefit ratio. Using the same data as for the DRC ratio but in a different relationship, the SCB ratio is defined as the ratio of the sum of domestic (non-tradable) and tradable input cost to the price of the good considered.

The Agricultural costs of production: In general, costs of production are compared for specific commodities. The difficulty is then how to allocate joint inputs, i.e. inputs used to produce several outputs. Ahearn *et al*. (1990) calculate the costs of production for one commodity (wheat in the United States) based on farmers' records of purchased inputs and on farmers' reports of machinery time allocation among activities. In addition to relying on declarations by farmers, other methods exist for the allocation of joint production costs.
The profitability measure: Profitability is obviously related not only to costs of production but also to revenue. Profitability can be defined in several ways, such as the difference between revenue and costs (gross margin), or the ratio between cost and revenue. As Harrison and Kennedy (1997) argued firms with positive profits indicate that they are able to create barriers preventing the entry of new firms (whose entrance would result in profits decreasing to zero for all firms in the industry), that is to say they are able to maintain their market shares and thus possess some type of competitive advantage. Market shares are sometimes mentioned as a way of assessing a firm's competitiveness, but the concept is often quantitatively measured by profitability variables.

Productivity and efficiency are often cited as indicators or measures of competitiveness, and the European Commissionconsiders it as the most reliable indicator for competitiveness over the long term (EC, 2009). A general definition of productivity is the ability of production factors to produce the output. It can be simply measured as a partial productivity indicator, relating output to one input (e.g. yields or partial productivity of labour), but this does not account for the possibility of either factor substitution or output substitution. By contrast, the more comprehensive measure of total factor productivity (TFP) (sometimes called the multi-factor productivity, MFP) is a ratio that relates the aggregation of all outputs to the aggregation of all inputs. This concept is often used in a dynamic framework, where change in TFP, that is to say productivity improvement, is investigated.

2.4.2.3*Policy Analysis Matrix (PAM)*

The PAM methodwas developed by Monke and Pearson (1989)and it is used to evaluate the level of competitiveness of any named crop production systems on the basis of ecological characteristics and technology. The construction of a PAM for an agricultural system allows calculation of private profitability – a measure of the competitiveness of the system at actual market prices. The calculation of private profitability or competitiveness is carried out in the first (top) row of the PAM matrix (Table 2.2). A second purpose of the PAM approach is to estimate the agricultural system's social profitability – the result if products produced and inputs used are valued in efficiency prices (social opportunity costs). The calculation of social profitability or comparative advantage is carried out in the second (middle) row of the PAM matrix (Table 2.2). The third purpose of PAM analysis is to measure the transfer effects of policies. By contrasting revenues and costs before and after the imposition of a policy, one can determine the impact of that policy. The PAM method captures the effects of policies influencing both products and factors of production (land, labor, and capital). The measurement of the transfer effects of policies is carried out in the third (bottom) row of the PAM matrix (Table 2.2).

The PAM is a product of two accounting identities; one of the identities definingprofitability as the differencebetween revenues and costs and the other measuring the effects of divergences (distorting policiesand market failures) as the difference between observed parameters and parameters that would exist if thedivergences were removed. By filling in the elements of the PAM for an agricultural system, an analyst canmeasure both the extent of transfers occasioned by the set of policies acting on the system and the inherenteconomic efficiency of the system (Monke and Pearson, 1989)

Profits are defined as the difference between total (or per unit) sales revenues and costs of production.This definition generates the first identity of the accounting matrix. In the PAM, profitability is measuredhorizontally, across the columns of the matrix, as demonstrated in Table 2.2. Profits, shown in the righthandcolumn, are found by the subtraction of costs, given in the two middle columns, from revenues, indicatedin the left-hand column. Each of the column entries is thus a component of the profits identity-revenuesless costs equals profits.

Each PAM contains two cost columns, one for tradable inputs and the other for domestic factors. Intermediateinputs-including fertilizer, pesticides, purchased seeds, compound feeds, electricity, transportation,and fuel-are divided into their tradable-input and domestic factor components. This process of disaggregationof intermediate goods or services separates intermediate costs into four categories-tradable inputs,domestic factors, transfers (taxes or subsidies that are set asidein social evaluations), and nontradable inputs (which themselves have to be further disaggregated so thatultimately all component costs are classified as tradable inputs, domestic factors, or transfers).

Table 2.2 Framework of Policy Analysis Matrix

	Revenue	**Costs**		**Profits**
		Tradable inputs	**Domestic Factors**	
Private	A	B	C	D
Social	E	F	G	H
Divergences	I	J	K	L

Source: Monke and Pearson (1989)

Table Notes:
Private profits, D,(D= A-B-C).
Social profits, H, (H= E-F-G).
Output transfers,1, (I= A-E).
Input transfers, J, (J= B-F).
Factor transfers, K, (K= C-G).
Net transfers,L, (L= D-H);

Some of the important ratio indicators for policy analysis that can be obtained from PAM table are:

Private cost ratio (PCR) $= \frac{C}{A-B}$

Domestic Resource Cost (DRC) $= \frac{G}{E-F}$

Effective Protection Coefficient (EPC) $= \frac{A-B}{E-F}$

Nominal Protection Coefficient on Output(NPCO) ratio $= \frac{A}{E}$

2.5 Empirical Applications of Production Frontiers in Agriculture

Frontier production function models have been applied in a considerable number of empirical studies both in agriculture and non-agricultural sectors since the pioneering work of Farrell (1957). Few among them were reviewed in this study as follows:

Coelli*et al.* (2002) estimated technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation using a nonparametric approach. For the dry season, mean

technical efficiency was 69.4%, allocative efficiency was 81.3%, cost efficiency was 56.2% and scale efficiency was 94.9%. The wet season results were similar with a few points lower. Inefficiency effects model results showed that large families were more inefficient, whereas farmers with better access to input markets, and doing less off-farm work were more efficient.

Wadud (2003) estimated technical, allocative and economic efficiency of farms using farm-level survey data for rice farmers in Bangladesh. He applied the stochastic efficiency decomposition techniques and DEA. Inefficiency effects are modeled as a function of farm-specific human capital variables, irrigation infrastructure and environmental factors. The results from both the approaches showed that there was substantial technical, allocative and economic inefficiency in production. The sample farmers, on average, could increase their rice production through the improvement of technical, allocative and economic efficiency without resort to technological improvements.

Dhungana*et al*. (2004) studied the economic, technical, pure technical, scale and allocative inefficiencies of Nepalese rice farms. DEA approach was adopted to estimate these efficiencies. Results indicated that average economic, allocative, technical, pure technical and scale inefficiencies were 34, 13, 24, 18, and 7%, respectively. Seed, labour, fertilizers and mechanical power contributed towards the significant variation in the level of inefficiency across sample farms. Inefficiency model was determined using a second stage Tobit regression model. Results revealed that farm-specific attributes such as the

farmers' level of risk attitude, the farm manager's gender, age, education and family labour endowment were associated with the variation in the efficiency.

Kwon and Lee (2004) adopted parametric and non-parametric production frontiers and compared with the estimated productivity using panel data on Korean rice production. It was estimated that parametric estimations were found to produce higher technical efficiency scores as compared to the non-parametric approach and productivity measures differed considerably between these approaches. Both approaches revealed that the main sources of growth in Korean rice farming had been technical change and productivity improvements in regions of the country that had been associated with low efficiency.

Chavas*et al*. (2005) investigated the economic efficiency of farm households at the household level, with an application to the Gambia. Technical efficiency, allocative efficiency and scale efficiency were estimated using non-parametric measurements. Results showed that the mean technical efficiency measure at household level ranged from 0.895 to 0.995. The Tobit model was used to determine technical efficiency model and results showed that incidence of herding, food insecurity, loans/withdrawals and land tenure security were significantly negatively related with technical efficiency.

Latruffe*et al*. (2005) analysed the technical and scale efficiency of Polish farms using DEA. Results showed that livestock farms were on an average, more technically and scale efficient that crop farms. Technical inefficiency was due to pure technical rather

than scale inefficiency. This evidence showed that the low-educational attainment of people engaged in agriculture was more important reason for these inefficient practices and 64% of livestock farms.

Baten*et al*. (2009) estimated Cobb-Douglas Stochastic frontiers in which the technical inefficiency effects are defined by a model with two distributional assumptions. The model involved is the time-varying inefficiency model applied to panel data. A truncated-normal and half-normal distributions were used in the model and the time-varying inefficiency effects was estimated. They observed that technical inefficiency has declined over the reference period and concluded that the truncated (at zero) normal distribution is preferable to the half normal distribution for the technical inefficiency effects.

Hussaini and Abayomi (2010) examine the technical and scale efficiency in vegetable crop production under Fadama in North central Nigeria, using DEA approach for a sample of 192 Fadama farmers. The result revealed a technical efficiency of 90% and 82 % for the scale efficiency. The result also showed that the average pure technical efficiency score of 93%.

Keremidou*et al.* (2011) estimated the technical efficiency, pure technical efficiency and scale efficiency of meat production industry of Greeks for the year 1994-2007, using the DEA approach. The result revealed a mean technical efficiency, pure technical efficiency and scale efficiency of 0.873, .832 and 0.95. The main sources of inefficiency were related to mismanagement and the excess usage of capital. Farm size did not have any effect on the efficiency.

Ogunwande*et al.* (2012) investigated the differences in the technical efficiency of small scale farmers using organic fertilizer and otherwise in Oyo State, Nigeria. Stochastic Frontier Production was used to assess the efficiency differentials for the groups. The result showed that the mean efficiency score for organic fertilizer users(OFUs) and inorganic fertilizer users(IFUs) were 0.95 and 0.87 respectively. The results for the return to scale of the farmers were 0.67 and 0.33 for OFUs and IFUs, respectively which revealed that organic farmers operated at the stage II while IFUs at stage I of the production surface. They recommended that organic fertilizer should be used by all farmers in the rainforest, as it improves soil quality and ultimately the crop yield.

Many studies have applied Metafrontier techniques (both DEA and stochastic metafrontier techniques) in agricultural production and few among them were reviewed in this study. Hailu*et al.* (2005) employed two non-parametric translog stochastic

metafrontier cost functions using a nonlinear maximum likelihood estimation procedure to compare the cost efficiency of Alberta and Ontario dairy farms for period 1984-96. Average cost efficiency for the pooled sample was approximately 89% indicating that there existed some potential for improvement in dairy farms.

Matawie and Assaf (2008) compared the DEA and SFA approaches inestimating the metafrontier model in the Australian health carefoodservice context. The results of their study revealed significantdifference between the group and metafrontier efficiencyresults, derived from the two approaches. In addition, they found no significantdifference between the efficiencyrankings of the different firms. The ranking of the technologygap ratios was also consistent across the two approaches.The results from the model estimation indicated that theoperations in the States of group 1 are producing onaverage more of their potential output with respect to themetafrontier technology than those operations In the States ofgroup 2.

Ayinde *et al.* (2009) examined the technical efficiencyand varietal-gap of rice production across three out of six geographical zones in Nigeria. Metafrontier approach was applied to a random sample of 675 rice farmers, in which the farmers were classified into three groups according to the variety of rice they planted. The three mainvarieties of rice planted were local (Ofada), improved (Mai-Nasara) and New Rice forAfrican (NERICA). Estimates of the frontier were obtainedassuming a translog functional form. Results revealed mean technical efficiency of 55%,58% and 57% for Ofada, Mai-Nasara and NERICA varieties, respectively. Farm size,hired labour, fertilizer, seed, age, gender, household size and amount of credit are thedeterminants of technical efficiency of farmers in Nigeria rice production. The averagevalues of varietal technology gap are more than 0.83 in all the varieties.

Villano*et al.* (2010) adopted metafrontier approach to estimate technical efficiency and thetechnology gap usingfarm-level data on the production of three different varieties of pistachio trees inKerman Province of Iran.Results show that, on average,very little difference exists in technicalefficiency between farms growing thedifferent tree varieties. But they indicate thatfarms growing the three varieties differ inthe use they make of inputs as measured bythe technology gap ratio. Ignoring the limits placed onincreasing technical efficiency because ofconstraints imposed by variety choice couldlead to incorrect conclusions about the scopefor farmers to improve their technicalperformance by adopting better farmingpractices. Being the first study to estimate ametafrontier in agricultural production based on crop variety in Iran, they concluded that it ismisleading to compare the performance of different tree varieties on the basis of yield perhectare alone.

Moreira and Bravo-Ureta (2010) compared technical efficiency and metatechnology ratios for dairy farms fromArgentina, Chile and Uruguay using the metafrontier approach. They found that the estimated average metatechnology ratios for Argentina, Chileand Uruguay are 83.8, 79.6 and 91.4%, respectively, andthese results are significantly different from each other. The technical efficiencies estimated with respect to the meatfrontier are 72.8, 65.8 and73.4% for Argentina, Chile and Uruguay, respectively. They also found that the average technical efficiencies for Argentina and Uruguay are not significantlydifferent from each other but are significantly higher than thevalue for Chile. The production frontiers for Argentina andUruguay are relatively close to the metafrontier, which suggests thatthese two countries might need to increase investments topromote local research to generate new technologies and/orsearch for technologies to adapt from more distant areas.

Otieno*et al.* (2011)analysed farmers' technical efficiency and willingness to comply with Disease Free Zones,across three main cattle production systems in Kenya. They applied the stochastic metafrontier model to estimate TE andtechnology gaps acrossthree main cattle production systems in Kenya and the determinants of TE were assessed usinga Tobit model.Results show that there is significant inefficiency in both the nomadic and agro-pastoralsystems, but less in ranches. Further, in contrast with the other two systems, ranches are foundto have higher meta-technology ratios (MTRs). The average pooled TE with respect to themetafrontier is estimated to be 0.69, which suggests that there is considerable scope toimprove beef production in Kenya. The main factors that are he found to have a positiveinfluence on TE include: use of controlled cattle breeding method, access to market contract,presence of farm manager, off-farm income and larger herd size.
Barnes *et al.* (2011) used a regional approach to measure technical efficiencies on dairy farms by employing the deterministic metafrontiermethod. They construct six super regions for the UK, i.e.Eastern, Western, Northern England, Wales, Scotland and Northern Ireland. Thestochastic frontier approach is applied to construct six regional frontiers and a pooled (UK)dataset for comparison. A likelihood ratio test rejects the null hypothesis that these regionsoperate under a common frontier which may indicate bias in previous attempts to measuredairying efficiency at the country level. The metafrontier presentsestimates against a common technology and mean scores range from below 0.50 for the Englishregions and Northern Ireland, 0.52 for Wales and 0.56 for Scotland. They recommend theapplication of the deterministic metafrontier approach for similar sub-country studies.

Ferdushil *et al*. (2011) examined the relative influence of preference of a stochastic metafrontier model to evaluate the technical efficiencies and meta-technology ratios of firms that may be classified into different regions but not have the same technology. They used panel data set of six different regional firms in Bangladesh. The results revealed low mean technical efficiency scores 17.7%, 15.9%, 13.4% and 26.9% for Dhaka, Chittagong, Rajshahi and Khulna regions respectively in Bangladesh. But these were found to be very high for Barisal and Sylhet regions. The mean values for the meta-

technology ratio imply that Sylhet regional firms produce, on the average, about 4% of the potential output given the technology available to the whole firm used for this study. Conversely, firms in Chittagong region produce, on the average, only about 1% of the potential output given the technology.

2.6 Empirical Application of PAM in Agriculture

Akande and Ogundele (2007)adopted PAM as an analytical tool to examine the effects oftrade and market liberalization on the incentive structure for technology adoption and increasingproductivity in the yam sector in Nigeria. Three yam production systems were identified and examinedin three yam production regions. Results show that yam production is profitable toproducers (private prices) and profitable to the economy (social prices). Nigeria also has acomparative advantage in yam production in the three production systems examined. Theincentive structure shows that yam producers are fairly protected as economic agents underthe existing macroeconomic and sectoral policy regimes.

Reig-Martínez*et al.* (2008) combinedPAM and data envelopment analysis techniques to model the analysisof profitability from rice production in the wetland of theEastern Spain under observed conventional and profit-efficient farming conditions.While conventional analysis points to a lack of profitability, farmers are shown to make positive profits at privateand social prices when data reflecting efficiency adjustments are used in the analysis. The main conclusion drawn from the study wasthat the usefulness of the policy analysis matrix might be substantially enhanced by simulating profitability afterefficiency-improving managerial decisions have been adopted.
Liverpool *et al.* (2009) employed PAM framework in their study on commodity value chain analysis of major agricultural commodities in Nigeria (cassava, maize, and rice) to assess private profitability and national economic growth. They analyze the direct and indirect effects(negative or positive) of various government policies along with the agricultural productionenvironment on farmers' profitability.The result from PAM analysis finds positive social profits for farmers withan average yield of 2.5 tons/ha who apply average (but not the most efficient) input use andother agronomic practices. The PAM analysis also finds that there is immensepotential in the Nigerian rice production system which can be harnessed through increasing farmer use of improved varieties, chemical fertilizers, and herbicides. The PAM analysis findsthat farmers with guaranteed input and output markets, as well as the necessary training,produced paddy rice with minimum mixed grain, generated much higher yields (more than 2times the national average yield), and are socially profitable. The potential for rice tocontribute to national growth is clearly evident from the PAM results.

Oguntade (2011) determined the contributors to value-addition in the processing of paddy rice into basic milled rice and value-added rice as well as analyze the comparative advantage and competitiveness of rice processing in Nigeria. The extent of policy distortion and agricultural protection was also determined by the study. Both primary and secondary were used for the study. The main analytical framework used was the PAM.

PAM results show that the price of value-added rice has been kept higher than the world price through policy interventions as the Nominal Protection Coefficient (NPC)on output was found to be 1.74. This result of positive value and greater than unity implies that farm gate price was greater than the international price of output. Government policy has, therefore, provided incentives to processors of paddy rice into value-added rice. Farmers producing paddy rice also benefited from Government protection as captured by NPC for tradable inputs, which was 1.27; paddy rice being the main tradable input into rice processing operations though it was profitable for a producer to process paddy rice into value-added rice given the policy environment, Nigeria has no comparative advantage in processing paddy rice into value-added rice, as the Domestic Resource Cost (DRC)ratio was computed to be more than unity (4.88).

In conclusion, the studies reviewed above show that several empirical studies were conducted on major agricultural enterprises mainly to explore factors that influence efficiencies of the farmers. The agricultural enterprises focusedby the researchers were rice, livestock, vegetable, meat industry, healthcare service, pistachio, etc. Parametric and non-parametric approaches to efficiency analyses were used in the above-mentioned studies. Most of the findings of the studies reviewed show that technical, allocative, overall and scale inefficiency were serious problems in the agricultural enterprises and it is, therefore, of prime importance to measure production inefficiencies of food security crop farms and its causes. Consequently, the present study will adopt comprehensively the two efficiency approaches to explore the factors that influence rice farmers' productivity and efficiency. Since no explicit reference is made to competitiveness in the reviewed studies of productivity and efficiency, this study hopes to use PAM to investigate the level of competitiveness in rice production at both ecological as well as international levels.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the Study Area

The Northern Nigeria comprises of about 52% of Nigeria's population (NPC, 2006) and is located between latitude 7^0 and 14^0N, and longitude 3^0 and 14^0E. It contains about 75% of Nigerians 993,773km^2 of land area and with climatic conditions suitable for agricultural production. The region has more than 400,000km^2 of arable land out of which only less than half of it is put under cultivation (FAOSTAT, 2012). Over 85% of the Nigerian paddy rice is produced in Northern Nigeria under the three major rice ecologies namely upland, lowland, and irrigated ecologies. These three major rice ecologies account for about 97% of the total rice output in Nigeria (Ededinma, 2005).

The overall climatic picture of the Northern part of Nigeria is that of weather markedly seasonal in character. From the southern border around Lokoja up to the northern fringes around Katsina, length of rainy season decreases from 7 to 4 months, while number of days of rain decreases from 200 to 80 days. Average annual rainfall also decreases northwards from a mean of 1,617mm to 433mm. The vegetation of northern Nigeria is mostly savanna, which consists of tropical grassland and shrubs as well as scattered woods (Oni, 2008). The region has 19 states out of which three states were selected for the study during reconnaissance survey. The chosen states were Kaduna, Niger and Kano States (Fig. 3).

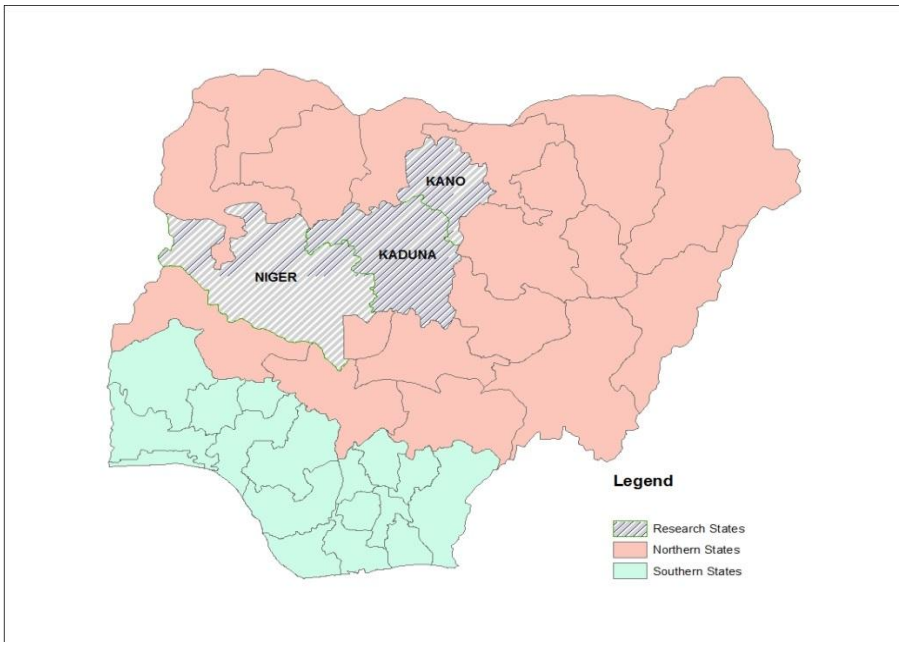


Figure 3: Map of Nigeria showing Northern and Southern parts and the study states

Kaduna State falls within the North West Agro Ecological Zone of Nigeria, occupying a land area of about 48,473.2km^2 (NAERLS, 2011). The state is located between latitude 9^0 10$^{"}$ and 11^0 30$^{"}$ N longitude 6^0 10$^{"}$ and 9^0 E. Based on NPC (2006), the State has a projected population of 7,287,295 as at 2012 with an annual growth rate of 3.2%. Majority (61%) of the population are engaged in farming and related activities as a means of livelihood. The mean annual rainfall is 1,524mm. The annual temperature ranges between 14.6^{0}C and 36^{0}C. The major crops grown in the State include rice, yam, cotton, ginger, cassava, maize, millet and groundnut (NAERLS, 2011).

Kano State is located between latitudes 13^0 N and 11^0 S and longitude 8^0 W and 10^0 E. The State has a land mass of about 20,760km^2 (NAERLS, 2011). As at 2012 the State has a projected population of 11,206,334 with annual growth rate of 3.2% (NPC, 2006). The

State is considered to be agrarian as more than 65% of the working adults are engaged in farming and related activities as a means of livelihood. The average annual rainfall is 700mm with the mean daily maximum and minimum temperatures of 35^0 and 19^0, respectively. The major crops grown in the State include rice, maize, millet, cowpea, vegetables and groundnut (NAERLS, 2011). TheKano River Irrigation Project (KRIP) is one of the pioneer large scale public irrigation schemes in Nigeria, established in 1969. The scheme has potential for irrigating 62,000 hectares of land but only the first phase, which covers an irrigable area of 25,606 ha, has been completed. The three local government areas that constituted the project site are Kura, Bunkure and Garun Mallam local government areas.The crops grown under the scheme include rice, maize and vegetables.

Niger state lies between latitude 8° 22'N and 11^0 30'N and longitude 3° 30'N and 7°20'E. It is situated in the middle belt zone of Nigeria covering about 74, 244km^2 or 8% of the total land area of the country. It is characterized with distinct wet and dry seasons with annual rainfall varying from 1,100mm in the Northern part of the State to 1,600mm in the Southern parts (NAERLS, 2011). Based on NPC (2006), the State as at 2012, has a projected population of 4,714,090 with annual growth rate of 3.2% and over 80% of this population engages directly or indirectly in agricultural activities. The major crops cultivated in the study area are; rice and guinea corn and others like maize, millet, yam and groundnut are also produced as minor crops (Jirgi *et al.*, 2009).

3.2Sampling Techniqueand Sample Size

The sampling technique used for primary data collection wasmulti-stage sampling technique. Out of the five rice production systems in Nigeria (Table 2.1), the study covered three major rice producing systems in Northern Nigeria. The three selected rice systemsare upland, lowland and irrigated systems and in each system a major rice producing State was selected. Thus, Kaduna, Niger and Kano States were purposively selected to represent upland, lowland and irrigated ecologies respectively. This was based on the intensive rice production activities under the said systemin a particular State. In each state the highest rice producing LGA was identified and selected purposively on the basis of accessibility and intensity of rice production. Then, a prominent rice producing village in each chosen LGA was also purposively selected. The list of rice farmers in each village was gathered during reconnaissance survey with aid of the staff of the State Agricultural Development Projects (ADP), the local union of rice producers association and Staff of NAERLS zonal offices. Field staff of Hadejia Ja'amare River Basis Development Authority (HJRBDA) werealso involved in the reconnaissance survey inthe Kano site. About 7% of the sampling frame of rice farmers in each village was taken randomly to form the working population for the study. Thus, a total of 278 rice farmers from the study areas constituted the sample size for the study (Table 3.1).

Table 3.1Sampling Distribution of Rice Farmers in the Study Area

System	**Selected State**	**Chosen LGA**	**Village chosen**	**Sample frame***	**Farmersselected at random7% usingproportional sampling**
Upland	Kaduna	Chukun	Kujama	1328	93
Lowland	Niger	Katcha	Ndayaki	1276	89
Irrigation	Kano	Kura	Kura	1377	96

Total	**3**	**3**	**3**	**3981**	**278**

Note: * obtained via reconnaissance survey

3.3 Methods of Data Collection

The study used both primary and secondary data. The secondary data were transportation costs, port charges, storage costs, production subsidy, import tariffs, and exchange rate and were obtained from the National Bureau of Statistics (NBS), Central Bank of Nigeria (CBN), Federal Ministry of Agriculture and Rural Development (FMARD). Information were further sourced from transporters, processors, traders, importers, exporters, and the Customs Department which were used to compute social prices in the policy analysis matrix.

Information related to production, processing and marketing and general background data such as socio-economic, institutions and demographic characteristics of the rice farmers were collected through the administration of structured questionnaire and oral interview. The structured questionnaire was pre-tested to evaluate its clarity, validity and reliability to generate the needed data to address the objectives of the study and to test the hypotheses.

3.4 Methods of Data Analyses

The primary and secondary data collected were analysed using appropriate techniques to achieve the objectives of the study and also to test the hypotheses. The tools of analyses used in this study include:

3.4.1 Descriptive statistics

Descriptive statistics such as the mean, standard deviations, frequency distribution and percentages were used to describe the social, economic, demographic and institutional

variables of the sampled rice farmers and the level of inputs and output of the rice production as well as constraints faced by rice farmers. The descriptive statistics were employed to achieve objectives 1 and 6 of the study.

3.4.2 Stochastic frontier models

This study specifies the stochastic frontier production function using the flexible transcendental logarithmic (or translog) specification. The empirical translog stochastic frontier production model for the study is expressed as:

$$lnY_i = \beta_0 + \sum_{k=1}^{4} \beta_k lnX_{ki} + \frac{1}{2}\sum_{k=1}^{4}\sum_{j=1}^{4} \beta_{kj} lnX_{ki} lnX_{ji} + V_i - U_i \ldots\ldots\ldots (3.1)$$

where,

lnstands for the natural log of the variables.

$Y_i$stands for the observed individual *i*th farmer's yield of rice (kg per hectare);

X_1 represents the quantity of seed (kg per hectare) used by the *i*th farmer;

X_2 indicates labour input consisting of family and hired labour and it was calculated as the total number of labour man-daysused to perform various farming activities on the *i*th farm (man-days per hectare);

X_3 shows the quantity of inorganic fertilizer used on *i*th farm (kg per hectare), and;

X_4 represents the total cost of irrigation and water management on *i*th farm (₦ per hectare);

β_s= vector of unknown parameters to be estimated

V_i = are random variables associated with random factors; and

U_i = which are non-negative random variables which are assumed to account for technical inefficiency in production.

Accordingly, technical efficiency (TE) of an individual farmer is defined in terms of the ratio of theobserved output (Y_i^*)to the corresponding frontier output (Y_i), conditioned on the level of inputsused by the firm. Technical inefficiency is therefore defined as the amount by which thelevel of production for the farmer is less than the frontier output. This is shown in equation (3.2)

$$TE_i = \frac{Y_i^*}{Y_i} = \frac{f(X_i\beta)exp(V_i - U_i)}{f(X_i\beta)exp(V_i)} = exp(-U_i) \ldots\ldots\ldots (3.2)$$

The translog stochastic cost function which is the basis for estimating the allocative efficiency (AE) of the farms is specified as follows:

$$lnC_i = \alpha_0 + \sum_{k=1}^{4} \alpha_k \, lnP_{ki} + \frac{1}{2}\sum_{k=1}^{4}\sum_{j=1}^{4} \alpha_{kj} lnP_{ki} lnP_{ji} + V_i + U_i \ldots\ldots\ldots (3.3)$$

where,

C_i stands for the total cost of production of the rice yield of *i*th farm on per hectare basis (₦);

P_1 indicates cost of seed per hectare (₦);

P_2indicates cost of total quantity of family (opportunity cost) and hired labour man-days required to perform various farming activities on the *i*th farm (₦ per hectare);

P_3 shows cost of quantity of inorganic fertilizer used on *i*th farm (₦ per hectare);

P_4represents the total cost of irrigation and water management on *i*th farm (₦ per hectare) and

α_s are vector of unknown parameters to be estimated

The sources of technical and allocative inefficiency effects U_i in equations (3.1) and (3.3) is modelled in terms of the farm's and farmer's characteristics and specified as:

$$U_i = \delta_0 \sum_{i=1}^{10} \delta_n Z_i \ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

where,

U_i = technical and allocative inefficiency effects of the equations (3.1) and (3.3) respectively;

Z_1 =age of the farmer in years;

Z_2 = years of rice farming experience;

Z_3 = years of schooling;

Z_4 = household size;

Z_5 = distance of seed market from the farmer's house (km);

Z_6 = numberof extension visits in the production season;

Z_7 = years spent in farmers' cooperative as a member;

Z_8 = amount of credit used on rice production (₦);

Z_9 = total size of rice farm (hectare);

Z_{10} = dummy for tenancy status of rice farmer (if the farmer is cultivating his land score one and zero otherwise;

These were included in the models (3.1 and 3.3) to indicate their possible influence on the technical and allocative efficiencies of the farmers.

The maximum – likelihood estimates of the β, α and δ coefficients in equations (3.1), (3.3) and (3.4) respectively were estimated simultaneously using the computer program FRONTIER 4.1 (Coelli, 1996) and the results obtained were used to achieve part of objective 2 and objective 3 and also tested the hypotheses 1 and 2.

The log likelihood ratio tests for the hypotheses 2 and 3 were done using the equation specified in model (3.5) and it is expressed as:

$$\lambda = -2\left\{ln\left[\frac{L(H_0)}{L(H_1)}\right]\right\} \; or \; -2\{ln[L(H_0)] - ln[L(H_1)]\} \ldots\ldots\ldots\ldots (3.5)$$

where $L(H_0)$is the value of the log likelihood functions for the stochastic frontier estimated by pooling the data for all the three rice production systems for the hypothesis 3 while it stands as log likelihood function for traditional response function for the hypothesis 2, and $L(H_1)$ is the sum of the values of the log likelihood functions for the three stochastic production functions (Upland + Lowland +Irrigation) estimated separately for the hypothesis 3 while it represents the log likelihood function for stochastic frontier function.

3.4.3 Economic efficiency (EE)

The product of allocative and technical efficiency scores provides an overall economic efficiency measure and was used to achieve part of objective 2. The combination of TE and AE provides the index of economic efficiency as given by:

$$EE = TE \times AE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

It is assumed that $0 \leq (TE \times AE) \leq 1$. Therefore, $(TE \times AE) = 1$ implies that a farmer is both technically and allocatively efficient. Alternatively, $(TE \times AE) < 1$ indicates that a farmer is not economically efficient, $[1 - (TE \times AE)]$ measures the proportional reduction that farmer can achieve by becoming technically and allocatively efficient.

3.4.4 Data envelopment analysis (DEA)

The output-oriented technical efficiency measure under the assumption of Constant Return Scale (CRS) for the rice production of the *i*th farmer in system is computed as the solutions of the mathematical problem as follows:

$$\theta_c^i = \max_{\theta_i \lambda} \theta$$

Subject to:

$$Y_m^i \leq \sum_{z=1}^{n} Y_m^z \lambda_z$$

$$\sum_{z=1}^{n} X_k^z \lambda_z \leq \theta X_k^i$$

$$\lambda \geq 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.7)$$

where,

θ_c^i is technical efficiency measure of *i*th farmer in a system under CRS; and

λ is (Nx1) vector of weight attached to each of the efficient farmer in that system.

A separate linear programming problem is solved to obtain the technical efficiency score for each of the N in the sample of particular rice production system. If $\theta_c^i = 1$, the farmer

is on the frontier and is technically efficient under CRS. If $\theta_c^i < 1$, the farm is said to be technically inefficient and lies below the frontier.

The variable return to scale (VRS) technical efficiency measure for the rice production of ith farmer in a systemis calculated as follows:

$$\theta_v^i = \max_{\theta_i \lambda} \theta$$

Subject to:

$$Y_m^i \leq \sum_{z=1}^{n} Y_m^z \lambda_z$$

$$\sum_{z=1}^{n} X_k^z \lambda_z \leq \theta X_k^i$$

$$\sum_{z=1}^{n} \lambda_z \leq 1$$

$\lambda \geq 0$ ……. (3.8)

Because the VRS analysis is more flexible and envelops the data in a tighter way than the CRS analysis, the VRS technical efficiency (θ_v) is generally equal to or greater than the CRS measure (θ_c). Therefore, this relationship was used to obtain a measure of scale efficiency (SE) of the rice production of *i*th farmer in systemas follows.

$$SE_i = \frac{\theta_c^i}{\theta_v^i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.9)$$

where, SE=1 indicates scale efficiency or CRS, and SE<1 indicates scale inefficiency. Scale inefficiency is due to the presence of either increasing or decreasing returns to scale, which can be determined by solving a non-increasing return to scale (NIRS) DEA model, which is in turn obtained by substituting the VRS constraint;

$$\sum_{z=1}^{n} \lambda_z = 1 \quad with \quad \sum_{z=1}^{n} \lambda_z \leq 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.10)$$

The NISR technical efficiency measure for the rice production of *i*th farmer in systemis computed as follows:

$$\theta_n^i = \max_{\theta_i \lambda} \theta$$

Subject to:

$$Y_m^i \leq \sum_{z=1}^{n} Y_m^z \lambda_z$$

$$\sum_{z=1}^{n} X_k^z \lambda_z \leq \theta X_k^i$$

$$\sum_{z=1}^{n} \lambda_z \leq 1$$

$$\lambda \geq 0 \qquad \text{…………………………….. (3.11)}$$

Let θ_n represents the technical efficiency measure under NIRS, if $\theta_n = \theta_c$, there are increasing returns to scale; and if $\theta_c < \theta_n$, there are decreasing returns to scale (Fare, *et al*., 1994). The efficiency scores in this study were estimated using the computer program, DEAPVersion 2.1 (Coelli, 1996) to achieve part of objective 2.

3.4.5 Stochastic metafrontier analytical framework

Following Aigner *et al.* (1977), Meeusen and van den Broaeck (1977), Battese *et al.* (2004) and O'Donnell *et al*. (2008), the stochastic metafrontier production function for all rice farmers in all rice production systems is defined as:

$$Y_i^* = f(X_i, \beta^*) e^{v_i^* - u_i^*} \equiv e^{X_i \beta^* + v_i^* - u_i^*} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots..(3.12)$$
$$i = 1, 2, \dots\dots n$$

where, $f(X_i, \beta^*)$ is a log-linear functional form; Y_i^* is the metafrontier riceoutput; and β^* denotes the vector of metafrontier parameters that satisfy the constraints:

$$X_i, \beta^* \geq X_i, \beta \quad \dots\dots\dots.\dots\dots\dots\dots.(3.13)$$

As shown in equation (3.13) the metafrontier dominates all the systems' frontiers. That is the metatechnologythat describes the unconstrained best practice according to the state of knowledge.The metafrontier production function is thus defined as a deterministic parametric function, such that its values are no smaller than the deterministic componentsof the stochastic frontier production functions of all the different systems involved.

The observed rice output for any farm can be accordingly defined by the stochastic frontier for the*jth* system (equation 3.1) using the metafrontier function (3.12), such that:

$$Y_i = e^{-u_i} \times \frac{e^{X_i\beta}}{e^{X_i\beta^*}} \times e^{X_i\beta^* + v_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.14)$$

The first term of the right-hand side of equation (3.14) is the technical efficiency relative to thestochastic frontier for the *jth* system.

$$TE_i = \frac{Y_i}{e^{X_i\beta + v_i}} = e^{-u_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.15)$$

The second term on the right-hand side of equation (3.14) is the technology gap (TGR) for thesample farmers involved,whose value is bounded between zero and one and is expressed as:

$$TGR_i = \frac{e^{X_i\beta}}{e^{X_i\beta^*}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.16)$$

This measures the ratio of the output for the frontier production function for the *jth* rice production system,relative to the potential output that is defined by the metafrontier function, given the observedinputs. The technology gap ratio ranges from zero to one because of equation (3.16). The technicalefficiency of the *ith* farmer, relative to the metafrontier, denoted byTE_i^*,is defined in ananalogous way to equation (3.16). It is the ratio of the observed output relative to the last term onthe right-hand side of equation (3.15), which is the metafrontier output adjustedfor thecorresponding random error, i.e.,

$$TE_i^* = \frac{Y_i}{e^{X_i\beta^* + v_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.17)$$

Deducting from the equations (3.14) to (3.17) an alternative expression for technical efficiency relative to themetafrontier is given by:

$$TE_i^* = TE_i \times TGR_i \ldots\ldots\ldots\ldots\ldots\ldots (3.18)$$

Equation (3.18) implies that the technical efficiency ratio of the *ith* rice producer relative to themetafrontier is the product of the technical efficiency relative to the stochastic frontier for thegiven system and the TGR. In other words, the technical efficiency scores for rice producers that don’tuse the same technology can be corrected (to make them comparable) using the distancebetween the system-based frontier and the leading metafrontier. Note that this precludes the technicalefficiency with respect to the meta-technology from being greater than the technical efficiencymeasure relative to the system-basedfrontier.

The β^* parameters can be estimated by solving the two different optimisation procedures (Battese *et al*.2004). One procedure relies on the sum of absolute deviations (linear programming) of the metafrontier values from those of the system frontiers, and the other procedure depends on the sum of squares of the same distances (quadratic programming).Given that $f(X_i, \beta^*)$in equation (3.1) is log-linear in the parameters, the optimisation procedure adopted in this study is the linear programming(LP) problem:

$$\min \sum_{n=1}^{N} \left[X_n, \beta^* - X_n, \hat{\beta}_j \right]$$

Subject to:

$$X_n, \beta^* \geq X_n, \hat{\beta}_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.19)$$

Empirically, the earlier stated equation (3.1) for the estimation of system TE and its determinants using FRONTIER 4.1 software was adopted here as the study model for metafrontier estimation and SHAZAM software was used for the estimation and the results obtained were used to achieve objective 4 and test hypothesis 3.

3.4.6 Policy analysis matrix framework

The Policy Analysis Matrix (PAM) was used to ascertain the level of competitiveness in the major Nigerian rice production systems, given the current technologies, prices of input and output and policy. Also, the PAM framework was employed to test hypothesis 4 of the study. Following Monke and Pearson (1989) and Masters and Winter-Nelson (1995), the PAM is depicted in Table 3.2, as a two-way accounting identity. Basically, it contains three rows and four columns, each showing specific identities.

To apply the PAM framework, the first step is to construct a table of private budgets, using quantities and prices of inputs and outputs in actual market prices. This private budgettable is based on budget data collected from farmers, traders, and processors. The next step is to construct a table of social budgets, using social prices for both inputs and

outputs. The social prices of tradable commodities were obtained by comparable world prices. Social price for tradable inputs was found by calculating import parity for imports goods and export parity prices for goods that enter export markets. The third row indicates the differences between the top row (private) and the second row (social), which are called divergences. These divergences indicate how much the private budget differs from social budget. The differences are caused by either market failures or distortions, which act as signals for policy intervention (Pearson and Gotsch, 2003).

Table 3.2 Framework of PAM

	Revenue	**Costs**		**Profits**
		Tradable inputs	**Domestic Factors**	
Private	A	B	C	D
Social	E	F	G	H
Divergences	I	J	K	L

Source: Monke and Pearson (1989)

Computationally,

$A = P_a \times Q_m; B = P_b \times Q_t;\ \ C\ = P_c \times Q_n;\ E = P_d \times Q_m;\qquad F = P_e \times Q_t;\ \ G = P_c \times Q_n;$

D (Private profit) = A–(B+C); H (Social profit) = E–(F+G); I (Output transfer) = A–E; J (Input transfer) = B–F; K (Factor transfer) = C–G; L (Net policy transfer) = D–H

Where,

P_a = average domestic price of milled rice (₦/kg) received by farmers;

P_b = average domestic price paid by farmers for tradable inputs{fertilizer (₦/kg), seed (₦/kg) and agrochemicals (₦/ltr)}

P_c = average market price of non-tradable inputs paid by farmer {hired labour (₦/man-day), water (₦/ha), capital (₦/ha)}

P_d = international price of milled rice (₦equivalent/kg)

P_e = international price of tradable inputs(fertilizer (₦/kg), seed (₦/kg) and agrochemicals (₦/ltr)

Q_m = average quantity of milled rice(kg)

Q_t = average quantity of tradable input {fertilizer (kg/ha), seed (kg/ha) and pesticides (ltr/ha)}

Q_n = average quantity of non-tradable input {total labour (man-day/ha), water (₦/ha), capital (₦/ha)}

The first row of Table 3.2 provides a measure of private profitability (D) or competitiveness, and is defined as the difference between observed revenue (A) and costs (B+C). Private profitability demonstrates the competitiveness of the rice production systems, given current technologies, prices for inputs and outputs, and policy interventions and market failures. The second row of the matrix calculates the measure of social profitability (H) defined as the difference between social revenue (E) and costs (F+G). Social profitability measures comparative advantage of the rice productionsystems.

3.4.6.1 *Ratio indicators*

The following important indicators for policy analysis were obtained from PAM (Monke and Pearson, 1989) to ascertain the level of competitiveness and to test the stated hypothesis for the study.

Private Cost Ratio:

The private cost ratio (PCR) is the ratio of factor costs (C) to value added in private prices (A-B). This ratio measures the competitiveness of a commodity system at the farm level. The rice system is competitive if the PCR is less than 1. Deductingfrom the PAM framework the PCR can be expressed as:

$$PCR = \frac{C}{A-B} = \frac{P_c \times Q_n}{\{(P_a \times Q_m) - (P_b \times Q_t)\}} \ldots\ldots\ldots\ldots (3.20)$$

Domestic Resource Cost Ratio:

The Domestic Resource Cost (DRC) ratio was brought into common use for the purpose of measuring comparative advantage. Since minimizing the DRC is equivalent to maximizing social profits, if the DRC ratio is less than 1, the system uses domestic resources efficiently. On the other hand,if the DRC ratio is greater than 1, then the system shows inefficiency in domestic resource use and possesses a comparative disadvantage. This was used to test the hypothesis 4. The method of calculating the DRC ratio in the PAM framework is given as:

$$DRC = \frac{G}{E-F} = \frac{P_c \times Q_n}{\{(P_d \times Q_m) - (P_e \times Q_t)\}} \ldots\ldots\ldots\ldots (3.21)$$

Effective Protection Coefficient :

The Effective Protection Coefficient (EPC) is the ratio of value added in private prices (A-B) to value added in social prices (E-F). An EPC value of greater than 1 suggests that government policies provide positive incentives to rice farmers, while values less than 1 indicates that rice farmers are disprotected through policy interventions on value added. EPC is given as:

$$EPC = \frac{A-B}{E-F} = \frac{(P_a \times Q_m) - (P_b \times Q_t)\}}{\{(P_d \times Q_m) - (P_e \times Q_t)\}} \ldots\ldots\ldots\ldots\ldots\ldots (3.22)$$

Nominal Protection Coefficient on Output:

The Nominal Protection Coefficient on Output(NPCO) ratio shows the extent to which domestic prices for output differ from international reference prices. If NPCO is greater than 1, the domestic farm gate price is greater than the international price of output and thus the system receives protection. On the contrary, if NPCO is less than 1, the system is disprotected by policy. NPCO is expressed as:

$$NPCO = \frac{A}{E} = \frac{P_a \times Q_m}{P_d \times Q_m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.23)$$

3.4.6.2.*Sensitivity analysis on the level of competitiveness*

Sensitivity analysis on the competitiveness level was done purposely to study how robust or sensitive the private profitability levels of the rice producing systems are to a changeof at least 10% in the private data like prices of fertilizer, price of milled rice output and the quantity of milled rice output. The basic idea is to be able to provideexplanations to questions of the form:

i. If the prices of fertilizer changes by at least 10%, how does the levels of private profitabilityof the systems change?

ii. If the domestic price of milled rice output changes by 10%, how does the level of private profitability change?

iii. If the quantity of milled rice output changes by 10%, how does the competitiveness levels of the three systems will response to the change?

CHAPTER FOUR

4.0RESULTS AND DISCUSSION

4.1 Socio-economicCharacteristicsofRice Farmers

In this section of results presentation and discussion,the majorsocio-economic characteristicsof the sampled rice farmers were described. The descriptions were done according to the rice system specific and the pooled population of the three rice systems. The main characteristics considered relate to farmers' age,farm size, farming experience in rice production, educational level, household size, sources of farm labour, maritalstatus, land tenure system, annual income, amount and sources of credit,contact with extension agents, among others. These characteristicsareindispensableto the understanding of the ricefarmers as thosecharacteristicshave direct effects on the farmers'behavior, decision making process and adoption of improved rice production technologies extended to them or available in the farming environment in which they conduct production activities.

4.1.1 Age of rice farmers

Farmer's age is one of thesignificantfactors that influence the extentof energeticand productive participationof an individual in rice production. This is predominantlynoticedin the traditional agricultural production system of the developing countries where most of the farm activities are carried out manually using crude and labour intensive farm implements.

The age distribution of the rice farmers according to the specific rice system and the pooled sampleis shown in Table 4.1. For the pooled rice farmers' population, the results indicate that over 88% of the rice farmers were within the active age bracket, which ranges from 26 to 55years. However, only a little over 9% were more than 55 years old. The mean age of the farmers is 43 years, while the minimum and maximum were 70 and 19 years respectively. Also, the average age of farmers under upland, lowland and irrigated systems were about 47, 41 and 42 years respectively. The implication of this result is that the farmers were in their highly productive age, which influences adoption of improved rice production practices.This result is in line with finding of a study carried out by Ayoola*et al.* (2011) in which they reported that majority of the rice farmers are within their active age bracket.Also, age has been found to affect the rate of household

adoption of innovations that in turn affect household productivity and livelihood improvement strategies (Akinola *et. al.,* 2008).

Table 4.1 Age distribution of farmers

Age	Upland		Lowland		Irrigated		Pooled	
(years)	Frq	%	Frq	%	Frq	%	Frq	%
16 – 25	0	0	7	7.9	1	1.0	7	2.52
26 – 35	15	16.1	24	27.0	10	10.4	53	19.06
36 – 45	30	32.3	28	31.5	41	42.7	101	36.33
46 – 55	47	50.5	19	21.3	30	31.3	91	32.73
≥ 56	1	1.1	11	12.4	14	14.6	26	9.35
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**
Mean	46.7		41.0		41.7		43.2	
Maximum	56		65		70		70	
Minimum	26		19		21		19	
S D	6.98		11.5		8.92		9.58	

Note: Frq and S D are the frequency and standard deviation respectively

4.1.2 Farm size of the farmers

The size of farmer's farm is an important production factor that is positively related with the level of rice output in Nigeria (Amaza and Maurice, 2005). The rice output,which is usuallydependent on various inputs and technologies for a given production season,dictates the quantity of rice supply to the market, food security leveland revenue accruing to the individual farmer. Table 4.2 shows the distribution of rice farmers according to their farm sizes. The result of the pooled sample showsthat about 82% of the farmershad farm size of less than 4.1 hectares, implying that rice production is mainly done by small scale farmers in the study area. The mean size of rice farm of the pooled sample farmers is 2.7 hectares, with minimum and maximum of 11 and 0.5 hectares respectively. Only about 3% of the farmers had a farm size exceeding 8 hectares.The average farm size of the upland and the irrigated rice farmers is 2.9 hectares each while that of lowland system is 2.4 hectares. A similar finding was reported by Saka and Lawal (2009) in their study on rice in which they found an average rice farm size to be 2.6 hectares.They are probably constrained by many problemsincluding those of land fragmentation, poor access to modern inputs and credit, land and environmentaldegradation andinadequate access to markets (Manyong *et al.,* 2005).

Table 4.2 Distribution of the farmers according to farm size

Farm size	Upland		Lowland		Irrigated		Pooled	
(hectare)	Frq	%	Frq	%	Frq	%	Frq	%

≤ 2.0	24	25.81	11	12.36	33	33.38	68	24.46
2.1 – 4.0	47	50.54	66	74.16	46	47.92	159	57.19
4.1 – 6.0	17	18.28	4	4.49	13	13.54	34	12.23
6.1 – 8.0	3	3.23	5	5.62	2	2.08	10	3.60
8.1 – 10.0	1	1.08	1	1.12	2	2.08	4	1.44
> 10.0	1	1.08	2	2.25	0	0.00	3	1.08
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**
Mean	2.9		2.4		2.9		2.7	
Maximum	11		11		9		11	
Minimum	0.5		1		1		0.5	
S D	2.14		2.30		1.82		2.12	

Note: Frq and S D are the frequency and standard deviation respectively

4.1.3 Rice farming experience

The rice production level and skill of farmer could be assessed based on thenumber of years spent in rice farming which can be determined by years of experience infarming enterprises. Expectedly, farmers with many years of experience are likely to be more efficient than their counterparts. This is because continuous doing of a particularwork increases the efficiency of the individual through learning by doing process.

The farming experience of the rice farmers is shown in Table 4.3. The result of pooled sample farmersindicates that about82% of the farmers have been producing rice for about 10 – 39 years. On the hand, about 18% had experience of less than 10 years while only about 1% had experience of greater than 39 years. The minimum years of farming experience in rice production under upland, lowland and irrigated systemswere6, 1 and 5years respectively.This implies more people are coming into rice production business in the study area because of the continuously increasing unexploited domestic market share. This finding agrees with the result of Saka and Lawal (2009) who reported that rice

farmers in southwestern Nigeria had about 17 years as average years of experience with minimum and maximum of 1 and 39 years in rice production.

Table 4.3 Distribution of farmers according to farming experience in years

Farming	Upland		Lowland		Irrigated		Pooled	
experience	Frq	%	Frq	%	Frq	%	Frq	%
≤ 9	3	1.08	30	33.71	6	6.25	50	17.99
10 – 19	39	11.83	41	46.07	43	44.79	112	40.29
20 – 29	39	41.94	15	16.85	37	38.54	91	32.73
30 – 39	11	41.94	3	3.37	9	9.38	23	8.27
40 – 49	1	3.23	0	0.00	1	1.04	2	0.72
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**
Mean	16.2		15.8		18.3		16.8	
Maximum	40		35		42		42	
Minimum	6		1		5		1	
S D	7.63		7.82		7.11		8.22	

Note: Frq and S D are the frequency and standard deviation respectively

4.1.4 Sex of the farmers

The frequency distribution of the sex of rice farmers in the study area is shown in Figure 4. The pooled population distribution shows that 251 rice farmers (90.3%) are male, while only 27 rice farmers (9.7%) are female, implying that the males dominaterice production in the study area.Similarly, the percentage of male farmers in upland and lowland systems were over 83% (74 male farmers) and 87% (81 male farmers) respectively while is 100% (96 male farmers) in irrigated system. This is in consonance with Tiku and Ugbada (2012) who reported about 86% of men dominance in rice production in Cross River. This is one of the unique features of agriculturalsector in the developing countries where most farm operations are carried out manually and therefore more demanding in terms of physical strength, especially for labour-intensive crops such as rice justifying the dominance of males over females in terms of access to production assets.Also, rice production is controlled by men while females assist their husbands in the cultivation, processing and marketing the products.

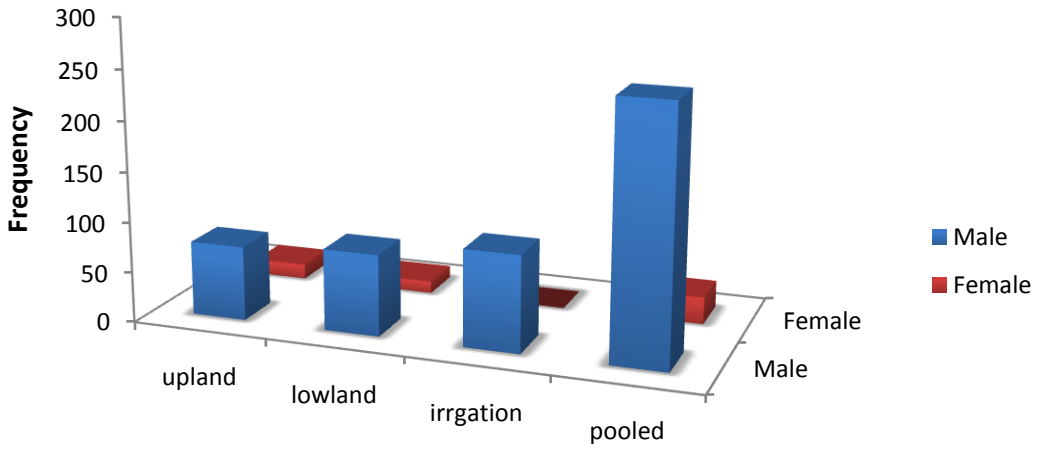


Figure 4. Frequency distribution of the respondents based on sex

4.1.5 Distribution of the farmers according to marital status

Generally, the marital status of a farmer influenceshislevel of involvementinthe agricultural production to supply food requirement to his household members for all year round.This is noticeable especially in traditional African societies,where married farmers are the main earner in the family. Therefore, they are expected to provide for the basic requirements of the members of his household.Per se, they are anticipated to be fully dedicated and thus very efficient in their agricultural businesses.

The frequency distribution of rice farmers according to their marital status is shown in Figure 5. As indicated by the result of pooled sample, greater frequency (234 farmers)of the respondents were married, while only 35 and 9 farmers were single and divorced respectively. Also, most of the farmers in the three systems were as shown by high frequencies of 74, 81 79 married farmers in upland, lowland and irrigated systems respectively. This high percentage of married people is an indication of more responsible adults in the study area and probably a good signal of efficient rice production. The high

percentage of married farmers is in line with the finding of Tiku and Ugbada (2012) that observed over 77% of rice farmersin Cross River were married.

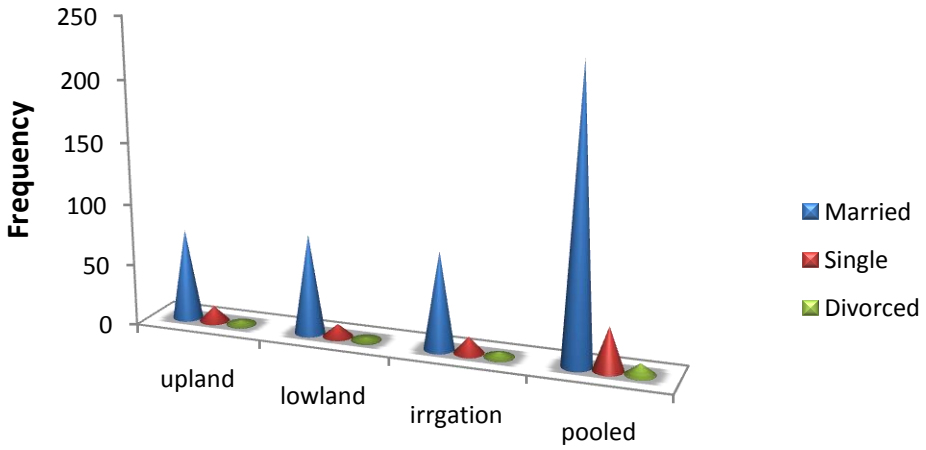


Figure 5. Frequency Distribution of farmers' marital status

4.1.6 Household size

In traditional agricultural production, the household size determines the available labour force to be employed in carrying out production activities. The major source of labour supply in labour intensive peasant farming system is the family labour. The household size distribution is shown in Table 4.4. Among the pooled population of rice farmers, over 85% were in the range of 1 – 14 persons in their households, while only a little over 2% had more than 21 persons in their households. The average household size for upland system are 7 persons, while for lowland and irrigated systems were about 9 and 8 persons respectively implying that there is a source of family labour and high food consumptionby the members in household. Consequently, increases in crops production to secure subsistence food needs become imperative.The finding is in agreement with that of Onumadu, and Osahon(2014) who reported a modal class of rice farmers' household size of 6 – 10 persons.

Table 4.4 Distribution of farmers based on household size

Household	**Upland**		**Lowland**		**Irrigated**		**Pooled**	
size	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**
1 – 7	38	40.86	32	35.96	67	69.79	100	35.97
8 – 14	34	36.56	42	47.19	24	25.00	137	49.28
15 – 21	18	19.35	13	14.19	4	4.17	35	12.59
22 – 28	2	2.15	1	1.12	1	1.04	4	1.44
≥ 29	1	1.08	1	1.12	0	0.00	2	0.72
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**
Mean	7.2		8.9		7.6		8	

Maximum	33	29	27	32
Minimum	2	1	2	1
S D	5.67	5.14	3.82	5.05

Note: Frq and S D are the frequency and standard deviation respectively

4.1.7 Years spent as membersin farmers' cooperative

The distribution of rice farmers according to the approximate number of years spent as member of any farmers' cooperative is shown in Table 4.5. For the pooled sample, the results revealed that over 59% of the farmershad years of membership in farmers' cooperative ranges from 7 – 12 years while only about 1% had belong to cooperative societies for more than 24 years.The mean years of membership in farmers' cooperative societies were about 9, 10 and over 16 years for upland, lowland and irrigated systems respectively. Membership of farmers' cooperatives usually gives farmers opportunity of not only easy access to quality and low prices agricultural inputs but also firsthand information and trainings on how to improve upon their farming activities and reapingthe benefits of group marketing and loans. The result affirms that of Usman *et al.* (2013) who found that the mean years of membership in farmers' cooperative among small-scale rice farmers in Kano was 13 years.

Table 4.5 Distribution of the farmers based on years spent as members in farmers' cooperative

Years in	**Upland**		**Lowland**		**Irrigated**		**Pooled**	
cooperative	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**
≤ 6	38	40.89	13	14.61	7	7.29	26	9.35
7 – 12	39	41.94	70	78.65	27	28.13	165	59.35
13 – 18	16	17.20	3	3.37	57	59.38	79	28.42
19 – 24	0	0.00	1	1.12	5	5.21	6	2.16
≥ 25	0	0.00	2	2.25	0	0.00	2	0.72
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**
Mean	8.6		9.5		16.3		12	
Maximum	18		25		26		26	
Minimum	2		0		0		0	
S D	4.32		5.02		5.70		5.21	

Note: Frq and S D are the frequency and standard deviation respectively

4.1.8Source of human Labour on the rice farm

Similar to any other traditional farm business, human labour input is a crucial factor in rice production. The sampled rice farmers in the study area have reporteddifferent major sources of rice farm labour which include family, hired andcombination of family and

hired labour.The distribution of the farmers according to their major source of human labour in rice production is shown in Table 4. 6.

For the pooled population, the study shows that majority of the farmers (55.8%) combined both family and hired labour in the study area duringthe production season, while over 34% and 10% employed solely family labour and hired labour respectively.Combination of family and hired labour is the common source of human labour in rice production in the three rice production systems.The hired labour is mostly employed during land preparation, weeding, harvesting and threshing. Consequently, the availability and affordability of family and hired labour can increase rice production in the study area even though cost of production will also increase.

Table 4.6 Distribution of the farmers according to source of labour

Source of labour	**Upland**		**Lowland**		**Irrigated**		**Pooled**	
	Frq	**%**	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**
Family only	34	36.56	29	32.58	32	33.33	95	34.17
Hired only	5	5.38	9	10.11	14	14.58	28	10.07
Both family and Hired	54	58.06	51	57.08	50	52.08	155	55.76
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**

Note: Frq is the frequency

4.1.9 Land tenure system

Land is one of the key factors of agricultural production. Land tenure system was investigated among rice farmers in the study area and the result is revealed in figure 6. The pooled sample resultindicated that over84% and over 7% of the farmers acquired their farm lands through inheritance and purchase respectively.While about 4%and 5% of the farmers possessed their land through gift and rent respectively.Also, about 80% of farmers in upland system and 95% of irrigated system's rice farmers obtained their farm lands through inheritance. Ordinarily, the different types of land tenure system serve as a basis for future land security and consequentlythe ability to stabilize agricultural production. Land tenure by purchase could be a more secured method of acquiring land

for commercial productive activities. The land tenure system through inheritance usually leads to land fragmentation resulting into smaller and uneconomic farm sizes for modern mechanization as common in traditional peasant agriculture in the developing countries.This result affirms the findings ofManyong *et al.* (2005) in which they asserted that the major land tenure system for agricultural activities in Nigeria was through inheritance.

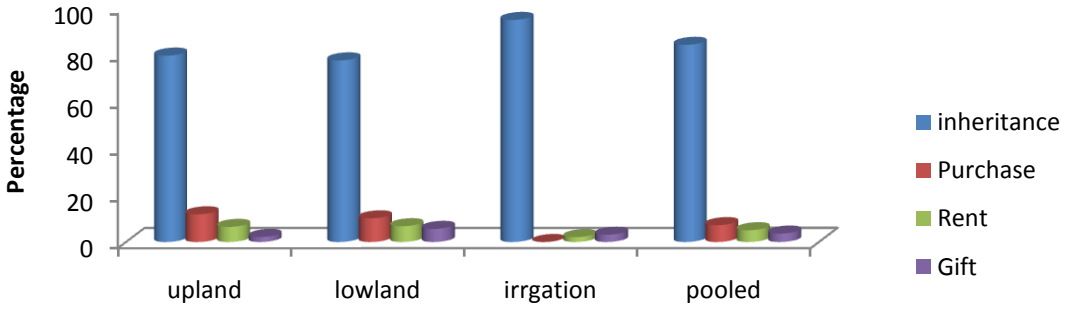


Fig. 6. Percentage distribution of farmers according to land tenure system

4.1.10 Education level attained by rice farmers

Literature isreplete on the influence of formal education on managerial capabilities of farmers, especially concerning awareness about production alternatives and the decision-making process. In most cases, empirical evidence has pointed to the positive impact of education on improving farmers' efficiency (Usman and Magaji, 2013) and, consequently, productivity(Reimers and Klasen, 2011). This has shapedthe main organizationof the universalconsensus on the positive impact of education on agricultural growth.

The distribution of educational attainment of rice farmers in the study area isshown in Table 4.7.As shownin the pooled sample result,a larger percentage (37.8%) had Qur'anic education. The percentage of those who had adult and post-primary education (secondary and tertiary school) wereover 23% and about 16% respectively, while a little over 8% had no formal education. The implication of this high literacy level among the sampled rice farmersindicates the availability ofappreciable potential for improved managerial capabilities among them.

Table 4.7 Distribution of farmers based on education level

Education level	Upland		Lowland		Irrigated		Pooled	
	Frq	%	Frq	%	Frq	%	Frq	%
Non formal	12	12.90	8	8.99	3	3.13	23	8.27
Qur'anic	32	34.41	22	24.72	51	53.13	105	37.77
Adult	17	18.28	32	35.96	16	16.67	65	23.38
Primary	21	22.58	13	14.61	7	7.29	41	14.75
Secondary	10	10.75	13	14.61	10	10.42	33	11.87
Tertiary	1	1.08	1	1.12	9	9.38	11	3.96
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**

Note: Frq is the frequency

4.1.11 Types of farm implement utilized

Table 4.8 indicates the types of implements used by the sampled rice farmers in the study area. As common in traditional farming, more than half (57.2%) of the pooled sample farmerswere reported to use traditional hand implements such as hoes, cutlasses, rake, drums and sickle while about 21% was reported to have combined traditional hand implements with animal drawn implements. Animal traction isprominent in the study area even though the high cost of work bulls and the implements constrained its full utilizations. For the upland and irrigated systems, about 24% of farmers in each system reported to combined hand tools and tractor service while it is a little over 19%in lowland system. Tractor services are mainlyemployed only during land preparations. Availability and affordability of tractor services can go a long way in making farmers to go into more commercial production through land expansion and mechanizing other aspects of rice production.

Table 4.8 Distribution of farmers based on types of farm implements used

Farm implements used	Upland		Lowland		Irrigated		Pooled	
	Frq	%	Frq	%	Frq	%	Frq	%
Hand implement	57	61.29	56	62.92	46	47.92	159	57.19
Hand implement/Animal traction	14	15.05	16	17.98	27	28.13	57	20.51
Hand implement/tractor	22	23.66	17	19.10	23	23.96	62	22.30
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**

Note: Frq is the frequency

4.1.12 Amount of credit used

The accessibility of farmers to creditat affordable rateis essentialto adoption of improved technologies and commercialization of agricultural enterprisesas it generally increases farmers' purchasing power and capitalbasis. The distribution of rice farmersaccording to the amount of credit borrowed to financetheir rice production in the surveyed production season is shown in Table 4.9.

The result of the study indicated that the rice farmers in the study area used different amount of credit to finance their rice farming activities. As shown in the pooled sample, the amount of credit used by the rice farmers ranged from zero to ₦120, 000 with an average amount of₦5, 000. About 90% of rice farmers were found to borrowless than

₦16, 000 for therice production in the seasonunder consideration while only about 8%borrowed between ₦16,000 and ₦30,000. Only 1% borrowed more than ₦55, 000. The average credits borrowed by farmers in upland and lowland systems were ₦2, 900 and ₦4, 800 respectively.

Table 4.9 Distribution of farmers according to the amount of Credit used (₦)

Amount of Credit (₦)	**Upland**		**Lowland**		**Irrigated**		**Pooled**	
	Frq	**%**	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**
≤ 15,000	84	90.32	72	80.90	90	94.79	249	89.57
16,000 – 30,000	7	7.53	10	11.24	5	5.21	22	7.91
31,000 – 55,000	0	0.00	4	4.49	0	0.00	4	1.44
56,000 – 75,000	0	0.00	1	1.12	0	0.00	1	0.36
76,000 – 95,000	0	0.00	1	1.12	0	0.00	1	0.36
≥ 96,000	2	2.15	1	1.12	0	0.00	1	0.36
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**
Mean	2,900		4,800		4,400		5,000	
Maximum	100000		120000		120000		120000	
Minimum	0		0		0		0	
S D	18533		17352		5650		15000	

Note: Frq and S D are the frequency and standard deviation respectively

4.1.13 Sources of fund to the farmers

Fund is the basic component of any business enterprises. The success and the failure of a business entity are largely influenced by the ability of the enterprise to secure fund to provide the necessary inputs as and when required at the appropriate quantity.As revealed by the pooled rice farmers population in Table 4.10, the majority (51.2%) of the rice farmers finances their rice production activities from their personal savings, about 12% and 7% from relative/friends and money lenders respectively, while over 2% and 1% sourced fund for rice production activities from government credit scheme and commercial banks/micro finance institution. Farmers need the credit to purchase improved technologies and this was reported as third pressing problems by upland and lowland farmers (Table 4.44).

The high percentage of personal savings across the three production systems implies that the rice farmers have little access to formal credit and financial institutions, which force them to relyheavily on their personal savings to finance their production activities.Reasons attributed to this may be poor accessibility to credit facilities and long formalities involved in securing loan from banks.It is a general believe among researchers of agricultural finance(Adebayo and Adeola, 2008; Usman and Suleiman, 2010) that farmers in Nigeria lack access to formal financial services which could enhance their capital basis, incomes and reduce poverty level through more investment in their farming businesses.

Table 4.10 Sources of fund to the farmers

Sources of fund	Upland		Lowland		Irrigated		Pooled	
	Frq	%	Frq	%	Frq	%	Frq	%
Personal saving	52	45.22	58	54.72	58	54.21	168	51.22
Traditional saving	32	27.83	22	20.75	13	12.15	67	20.43
Relative/friends	11	9.57	10	9.43	18	16.82	39	11.89
Money lenders	9	7.83	7	6.60	6	5.61	22	6.71
Input/output dealers	9	7.83	5	4.72	7	6.54	21	6.40
Govt credit scheme	1	0.87	3	2.83	3	2.80	7	2.13
Bank/Micro finance Institution	1	0.87	1	0.94	2	1.87	4	1.22
Total	**115***	**100**	**106***	**100**	**107***	**100**	**328***	**100**

Note: * multiple responses allowed and Frq is the frequency

4.1.14. Information source on improved rice production practice

Rice farmers obtained information on improved rice production practicesthroughdifferent multiple sources which include extension agents, extension bulletins, farmers' group and mass media.The farmers' distribution according to their sources of information on improved rice production practices is shown in Table 4.11. As revealed in the table, over 56% of the pooled sampled farmers gottheir information from extension agent, about 6% and over 19%from Extension bulletins and mass media respectively.However, 1% of the farmers showed that they did not receive information of improved rice production practices in either of the mentioned sources. The main source of improved rice production technologies across the three systems is through the extension agent. Therefore, theextension agents are the key sources of information onthe improved rice technology. Thus, the more the farmersreceive visits from the extension agents, the more tendency ofadopting improved technology. This in turn would lead toincrease rice productivity and efficiency.

Table 4.11 Distribution of the farmers according to information source on improved rice production practice

Information source	Upland		Lowland		Irrigated		Pooled	
	Frq	%	Frq	%	Frq	%	Frq	%
Extension agent	51	43.59	67	66.34	71	60.68	189	56.42
Extension Bulletin	12	10.26	2	2.47	5	3.65	19	5.67
Farmers' Group	14	11.97	13	16.05	31	22.63	58	17.31
Mass Media	39	33.33	17	20.99	9	6.57	65	19.40
Not at all	1	0.85	2	2.47	1	0.73	4	1.20
Total	**117***	**100**	**101***	**100**	**117***	**100**	**335***	**100**

Note: * multiple responses allowed and Frq is the frequency

4.1.14Extension visits

The extension agents serve as a linkagebetween the agricultural research institutes and the target farmers. The agents convey new productive ideas to farmers as a solution to one or more of their existing field problems and at the same time carry back other

farmers' problems or reactions to the research institute for proper solutions. As such they play a vital role in educating and enlightening the farmers on the new and improved techniques and innovations in agricultural production. As observed by Usman *et al.* (2013) the number of extension visit positively influenced the utilization and adoption of modern technology and innovations in rice production in Kano State.Also, Omobolanle (2008) noted thatthe higher the frequency of extension contact, the higher the likelihood of the farmers accepting the improved farming innovations.

Table 4.12 shows the frequency of extension visits in the surveyed season.The result from pooled rice farmers' sample revealed that the majority (87.1%) of the rice farmers had an extension visits ranges from 0 to 4 times in the surveyed production season. Similarly, over8%, about 4% and about 1% of the farmers had a number of extension visits that falls within the range of 5 – 7, 10 – 14 and 15 – 19 respectively.For the upland and lowland systems respectively, only about 12% and 9% of the farmers had more than four times extension contact in the surveyed season. This implies that the rice farmers had limited access to extension services. This might be the reason why the large percentage of the farmers was credit constrained, recorded low yield and low returns. This finding also agrees with those of Omobolanle (2008), Kudi*et al.* (2011)and Usman *et al.* (2013) who reported that farmers in developing countries had little or no extension visits.

Table 4.12 Distribution of rice farmers according to the frequency of extension visits

Number of visits	**Upland**		**Lowland**		**Irrigated**		**Pooled**	
	Frq	**%**	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**
≤ 4	82	88.17	81	91.01	79	82.29	242	87.05
5 – 9	8	8.60	6	6.74	9	9.38	23	8.27
10 – 14	3	3.23	2	2.25	5	5.21	10	3.60
15 – 19	0	0.00	0	0.00	2	2.08	2	0.72
≥ 20	0	0.00	0	0.00	1	1.04	1	0.36
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**

Note: Frq is the frequency

4.1.16Fertilizer use

Fertilizer is one of the inputs required in rice production for optimum output. This is because it helps to replenish soil fertility, thereby increasing the yield of rice per unit area of cropped land. The types of fertilizers that are commonly applied on ricefarms are NPK and Urea while the latter is mainly applied 6 – 7 weeks after sowingand the former is applied at the sowing (Ekeleme*et al.*, 2008).

In the study, an attempt was made to investigate the approximate quantity of 50 kg bags of fertilizer used by the sampled rice farmers and the result is shown on Table 4.13.Over71% of the pooled sampled farmers used 1.0–4.9bags of 50kgof fertilizer while only a little over 4% had applied quantity of fertilizer of more than 6.9bags of 50kg of fertilizer. The average, minimum and maximum quantity of fertilizer applied were 2.1, 0 and 11.3 bags of 50kg of fertilizer respectively. This finding is below the recommended rate of about 6 bags of 50kg of fertilizer given by Ekeleme*et al.*(2008).This indicates that the commodity is not adequately applied by the farmers probablybecause ofits high price, credit constraint and low financial investment attitude of the farmers.

Table 4.13 Distribution of respondents based on number of 50kg bags of fertilizer utilized

Number of fertilizer	**Upland**		**Lowland**		**Irrigated**		**Pooled**	
bags	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**
< 1.0	19	20.43	11	12.36	9	9.38	39	14.03
1.0 – 2.9	47	50.54	41	46.07	47	48.96	135	48.56
3.0 – 4.9	19	20.43	27	30.34	25	26.04	71	25.54
5.0 – 6.9	5	5.38	5	5.62	11	11.46	21	7.55
7.0 – 8.9	3	3.23	2	2.25	1	1.04	6	2.16
9.0 – 10.9	0	0.00	3	3.37	1	1.04	4	1.44
≥11.0	0	0.00	0	0.00	2	2.08	2	0.72
Total	**93**	**100**	**89**	**100**	**96**	**100**	**278**	**100**

Note: Frq is the frequency

4. 1.16 Differences insocio-economic characteristics among rice farmers under the three different production systems.

The analysis of variance test of mean difference was used to determine the differences among the variables means of the farmers from the three rice production systems. Comparison was made on some socio-economic variables like age, years of farming experience, years of schooling, farm size, quantity of fertilizer used, number of extension contact during the surveyed rice production season, household size, amount of credit used, quantity of human labour in man-day used, years spent as member of farmers' cooperative and total quantity of rice output obtained in the season. The result is presented in Table 4.14.

The results indicated that there are significant differences among the three rice farmers groups on variables such as total rice output obtained, quantity of human labour used,

years spent as member of farmers' cooperative and total amount of credit used. All other variables compared were not significant at 10% level.The averages of the quantity of human labour (man-day) used by the farmers from upland, lowland and irrigated rice production systems were 34.2, 36.1 and 39.7 respectively and the difference among these means is statistically significant at 10% level ($p<0.10$). The mean amount of human labour is higher in irrigation system probably because of extra amount of labour needed in water application and management. Similarly, the means differences of the years spent as member of farmers' cooperative, quantity of output obtained and amount of credit used of the three rice production systems were statistically significant at 1%, 5% and 5% respectively. The mean year spent as member in farmers' cooperative of rice producers under irrigation is higher (16.3years) possibly because farmers within the Kano River Irrigation Project (KRIP), from where the sample was drawn, were mobilized long ago to form a group called Water User Association. This probably may contribute to the higher yield obtained by the irrigation farmers compared to other farmers, since group access to improved production inputs and group output marketing may positively affect production ability of a farmer.

Table 4.14 Differences in socio-economic characteristics among the farmers across the systems

Characteristics	**Upland (n=93)**	**Lowland (n=89)**	**Irrigation (n=96)**	**ANOVA F**	**sig**
Age (years)	46.7	41.0	41.7	1.197	0.2201
Years of rice Farming experience	16.2	15.8	18.3	0.322	0.6721
Years of schooling	4.7	3.6	4.6	0.144	0.7991
Farm size (ha)	2.9	2.4	2.9	0.684	0.4921
Fertilizer (kg/ha)	90	95	100	1.278	0.1262
Number of extension visits	3.4	3.3	5.7	0.287	0.5927
Household size (persons)	7.2	8.9	7.6	1.566	0.4137
Amount of credit used (₦)	2,900	4,800	4,400	2.136	0.0411**
Labour (man-days/ha)	34.2	36.1	39.7	1.693	0.0924***
Years in farmers' cooperative	8.6	9.5	16.3	3.811	0.0001*
Paddy yield (kg/ha)	1989.6	2170.5	3174.1	1.714	0.0851**

Note: * significant at 1% level, ** significant at 5%, *** significant at 10%.

4.2 Technical, Allocative, Economic and Scale Efficiencies Estimations

4.2.1 Technical efficiency estimates of rice production systems

The maximum likelihood estimates of the parameters of translog stochastic productionfrontier model defined by equation (3.1) and the specification for the inefficiency effectsmodel defined by equation (3.3) were obtained simultaneously for each rice production system using FRONTIER 4.1 software (Coelli, 1996) and for the full computer results of upland, lowland and irrigated systems see Appendices 2, 3 and 4 respectively. The results of the translog productionfunction frontier parameters estimates segmentsfor the three rice production systems are presented in Table 4.15.

From the results, the significance of sigma squared (σ^2) across the three rice production systems indicates that the models are all stochastic,not deterministicand the half-normal distributional assumption made on the inefficiency effects in the study model wasappropriate.Additionally, the values of gamma (γ)from the three systems imply that 73%, 75% and 63% of the divergences between the observed output of paddy rice and the frontieroutput for upland, lowland and irrigated rice production systems, respectively, can be ascribed to farmers' inefficiency. Furthermore, as shown in the Table, the shortfall of all mean technical efficiency scores from maximum efficiency of score 1.0indicates the presence of measurable technical inefficiency in rice production in the three systems. This suggests that there is scope to improve rice production by approximately 36%, 39% and 27% in upland, lowland and irrigated systems respectively from thecurrent technologies employed in the rice production across the three systems.

In agreement with the assumption of the theory of farmers rationality (Coelli *et al*., 2005), the coefficient of the estimated input variablesin the three rice production systems are all positive (Table 4.15). Thus, as anticipated for a continuously differentiable production function, the input elasticities satisfy the regularity state of monotonicity (Sauer *et al*., 2006). Monotonicity implies the production frontiers are non-decreasing in inputs usage (Coelli *et al*., 2005). In the first order variables, seed and fertilizer variables are all significant at 5% levels across the three rice production systems, while cost of irrigation and water management variable is only significant at 1% level in the irrigated system of rice production as expected. Labour is statistically significant at the 1%level in upland and irrigated systems and significant at 5% level in lowland system. Thus, labour is the most significant input in the production of rice in the study area. This is expected since most of the rice production in Nigeria uses traditional technology that relies heavily on human labourwhich is mainly supply by household members. Similar results were reported by Saka and Lawal (2009) and Amaza and Maurice (2005).

In the second order variables, an interactive variable for seed and fertilizer had positive sign across the three rice production systems indicating that the two variables interactively have positive impact on the quantity of output. This relationship is significant at the 5% level in upland and irrigation but significant at 10% level in lowland system. Therefore, improving farmers' accessibility to seed especially improved ones and fertilizer at affordable prices on timely basis as well as access to extension guides on the use of such inputs at recommended rateswill go a long way in increasing farmers' output. This finding is consistent with a study by Saka and Lawal (2009) for the rice farmers in Southwestern Nigeria, where they found evidence that seed and fertilizer have a positive impact on rice output.

Table 4.15. Maximum likelihood Estimates of the Translog Stochastic productionfrontiers

Variables	**Rice Production Systems**		
	Upland	**Lowland**	**Irrigation**
	Coefficient	**Coefficient**	**Coefficient**
$Constant\ (\beta_0)$	3.462 (0.770)*	8.933 (0.902)*	8.733 (1.331)*
$lnseed\ (\beta_1)$	0.223 (0.099)**	0.904 (0.423)**	0.600 (0.303)**
$lnlabour\ (\beta_2)$	0.053 (0.019)*	0.014 (0.006)**	0.106 (0.023)*
$lnfertilizer\ (\beta_3)$	0.100 (0.047)**	0.013 (0.007)**	0.075 (0.030)**
$lnirrg\ (\beta_4)$	0.564 (4.018)	0.262 (0.199)	0.737 (0.205)*
$lnseed^2\ (\beta_5)$	0.256 (0.285)	0.308 (0.217)	0.350 (0.176)**
$lnlabour^2\ (\beta_6)$	0.848 (0.402)**	0.189 (0.100)**	0.905 (0.680)
$lnfertilizer^2(\beta_7)$	0.042 (0.080)	0.112 (0.067)***	0.041 (5.159)

$lnirrg^2$ (β_8)	0.211 (0.210)	0.016 (0.016)	0.056 (0.019)*
$lnseed \times lnlabour$ (β_9)	0.061 (0.007)**	0.016 (0.154)	1.310 (0.399)*
$lnseed \times lnfertilizer$ (β_{10})	0.426(0.215)**	0.004 (0.003)***	0.074 (0.037)**
$lnseed \times lnirrg$ (β_{11})	0.761 (0.603)	0.068 (0.058)	0.677(0.399)***
$lnlabour \times lnfertilizer$ (β_{12})	1.045 (0.561)**	0.290 (0.130)**	0.218 (0.113)**
$lnlabour \times lnirrg$ (β_{13})	0.320 (0.559)	0.036 (0.043)	0.912 (0.126)*
$lnfertilizer \times lnirrg$ (β_{14})	0.952 (0.822)	0.080 (0.049)	0.321 (0.117)*
Variance Parameter			
Sigma-squared	0.041 (0.014)*	0.300 (0.042)*	0.071 (0.024)*
Gamma	0.706 (0.141)*	0.745 (0.343)**	0.626 (0.163)*
Log-likelihood	54.23	46.67	61.35
Mean Efficiency	0.643	0.622	0.734
Sample size	93	89	96

Note: * significant at 1% level, ** significant at 5%, *** significant at 10%.
Figures in parentheses are the standard errors

4.2.1.1*Technical efficiency scores in rice production*

The technical efficiency of individual rice farmer under the three production systemswas estimated using equation (3.2) and the frequency distribution of the scores is presented in Table 4.16. It was foundthat the technical efficiency scores among the upland rice farmers ranged from 0.16to 0.98 with a mean of 0.64,implying that the average farm producing upland rice could increase its technical efficiency by 36%through adoptionof the techniques and technology used by the best upland rice farmers.Similarly, technical efficiency scores among the lowland and irrigated rice farmers ranged from 0.13 to 0.96 and from 0.16 to 0.99 with the means of 0.62 and 0.73 respectively.

Though the meansdifference in technical efficiency of the three groups of rice farmers was not statistically significant as indicated by ANOVA result (F = 1.064; p=0.3646). The technical efficiency mean score is higher among irrigated farmers and also the distribution of technical efficiency scores among thefarmerswas more even than upland and lowland as indicated by standard deviations values.Nonetheless, the results imply that a considerable amount of output close to maximum attainable output can be obtained byimproving technical efficiency of the farmers in all the three rice production systems. As seen from the table, only a little over 3% and 2% about 13% of the farmers from upland, lowland and irrigated systems respectively have exceeded technicalefficiency score of 89%.

Table 4.16 Frequency distribution of technical efficiency estimates for rice farmers

	Upland		**Lowland**		**Irrigation**	
Efficiency Scores	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
≤ 0.29	7	7.53	9	10.11	2	2.08
0.30 – 0.49	8	8.60	15	16.85	7	7.29
0.50 – 0.69	65	69.89	47	52.81	32	33.34
0.70 – 0.89	10	10.75	16	17.98	43	44.79
≥ 0.90	3	3.23	2	2.25	12	12.50

Total	**93**	**100**	**89**	**100**	**96**	**100**
Mean TE	0.643		0.622		0.734	
Maximum	0.978		0.956		0.986	
Minimum	0.161		0.130		0.162	
Standard deviation	0.381		0.459		0.160	
ANOVA (F = 1.064; p= 0.3646)						

4.2.1.2 *Production loss due to technical inefficiency*

The production loss (Table 4.17) due to technical inefficiency was computed as thedifference between the observed average production level and the production levelif the farmers were technically 100% efficient (equation 3.2). Estimation shows thatproduction losses were1044.7kg/ha, 1319.1kg/ha and 1150.3kg/ha among the rice farmers in upland, lowland and irrigation systems respectively.While the corresponding yield loss as percentage of the observed yields for upland, lowland and irrigated systems were about 56%, 61% and 36% in that order. This shows that efficient inputs and output combinations are better achieved by irrigatedfarmers which made them to minimize losses caused by inefficiency as compared to others. One of the reasons behind less yield lossesamongirrigation farmers is probably due to relative higher number of extension agents visits, years in farmers' cooperative and years of experience in rice production (Table 4.14) as compared with their counterparts, which may influence adoption of improved technology rice production.

Table 4.17 Rice yield loss due to technical inefficiency

	Rice Production Systems		
Variables	**Upland**	**Lowland**	**Irrigation**
Mean TE (%)	64	62	73
Frontier yield (kg Ha^{-1})	3094.3	3489.6	4324.4
Observed yield (kg Ha^{-1})	1989.6	2170.5	3174.1
Yield loss (kg Ha^{-1})	1044.7	1319.1	1150.3
Loss as % of observed yield	55.5	60.8	36.2

4.2.2Allocative efficiency of rice production systems

The maximum likelihood estimates for the parameters of the translog Stochastic Cost Frontiers (equation 3.3) of rice farmers in each of the three production systems in the study area were presented in Table 4.18. The full computer results of the estimates of the translog Stochastic Cost Frontiers for upland, irrigated and lowland systems were appended as Appendices 6, 7 and 8 respectively. The estimates of sigma squared (σ^2) and the gamma (γ) for upland, lowland and irrigated systems were all significant at 1% levels, implying goodness of model fit and correctness of the half normal distributional assumption made on the inefficiency error term. The estimated gammaparameter (γ) for the cost functionswere 0.826for upland, 0.852 for lowland and 0.792 for irrigated system,indicating that about 83%, 85% and 79% of the variations in thetotal cost of rice production among the upland, lowland and irrigated farmers respectively were due to the

presence of allocative inefficiencies. Rice productions under the three systems are allocatively inefficient as indicated by their mean values of less than one. For the full computer results see Appendix 2.

The estimated first order variables coefficients of the parameters of translog stochastic cost functions for the three production systems were significant and positively related with cost of rice production per hectare as explained variable except price of irrigation/water management which is significant only in the irrigated system of rice production.This implies that theexogenous variableson hectare basis (price of seed,price of total human labour, price of fertilizer andprice of irrigation/water management) used in regressionanalysis have direct relationship with costof production in all the three rice production systems. Price of labour and price of seed variables were significant at 1% and 5% respectively in upland and irrigated systems while they were significant at 10% level in lowland system of production. The variable price of irrigation/water management was significant at 1% in irrigated system while the price of fertilizer was also significant at 1% level in all the three production systems. The significance levels of these independent variables indicate their importance in the cost structure of the rice farmers.

Furthermore, sevenout of the ten interaction variables (second order coefficients) were statistically significant at varying levels of significance, implying that suitability of the translog functional forms (Okoye and Onyenweaku, 2007). The second order variables that are statistically significant in the analysis include price of seed squared, price of fertilizer squared, price of labour squared, interaction of price of seed/price of fertilizer, interaction of price of labour/price of fertilizer, interaction of price of seed/price of labour and interaction of price of labour/price of irrigation.Among thesestatistically significant second order variables, the coefficients of the squared terms for the price of seed and the price of fertilizer are significant at 5% levelsin all the systems. The interactions of price of seed/price of fertilizer, price of labour/price of irrigation are positive and highly significant at 1% level in irrigation system.

Table 4.18. Maximum likelihood Estimates of the Translog Stochastic cost Frontiers

Variables	**Rice Production Systems**		
	Upland	**Lowland**	**Irrigation**
	Coefficient	**Coefficient**	**Coefficient**
$Constant\ (\alpha_0)$	3.449(0.401)*	0.374(0.100)*	5.400(1.120)*
$lnpseed\ (\alpha_1)$	0.314(0.157)**	0.015(0.081)***	0.048(0.024)**
$lnplab\ (\alpha_2)$	0.079(0.025)*	0.613(0.315)***	0.767(0.102)*
$lnpferti\ (\alpha_3)$	0.047(0.015)*	0.682(0.090)*	0.597(0.0948)*
$lnpirrg\ (\alpha_4)$	0.976(0.854)	0.044(0.356)	0.160(0.033)*
$lnpseed^2\ (\alpha_5)$	0.189(0.073)**	0.778(0.389)**	0.525(0.243)**
$lnplab^2\ (\alpha_6)$	0.241(0.112)**	0.285(0.220)	0.377(0.052)***

$lnpferti^2$ (α_7)	0.160(0.066)**	0.341(0.142)**	0.301(0.116)**
$lnpirrg^2$ (α_8)	0.155(0.556)	0.222(0.200)	0.781(0.458)***
$lnpseed \times lnplab$ (α_9)	0.417(0.048)**	0.419(0.236)**	0.059(0.037)***
$lnpseed \times lnpferti$ (α_{10})	0.028(0.023)**	0.022(0.023)***	0.061(0.018)*
$lnpseed \times lnpirrg$ (α_{11})	0.059(0.213)	0.055(0.162)	0.032(0.017)***
$lnplab \times lnpferti$ (α_{12})	0.009(0.004)**	0.013(0.012)	0.960(0.501)***
$lnplab \times lnpirrg$ (α_{13})	0.0189(0.069)	0.061(0.078)	0.069(0.014)*
$lnpferti \times lnpirrg$ (α_{14})	0.002(0.001)	0.014(0.011)	0.037(0.0133)**
Variance Parameter			
Sigma-squared	0.146 (0.044)*	0.072 (0.016)*	0.104 (0.038)*
Gamma	0.825(0.092)*	0.852 (0.029)*	0.792 (0.090)*
Log-likelihood	55.806	61.342	64.1645
Mean Efficiency	0.462	0.381	0.514
Sample size	93	96	89

Note: * significant at 1% level, ** significant at 5%, *** significant at 10%.
Figures in parentheses are the standard errors

4.2.2.1*Distribution of the allocative efficiency scores*

The frequency distributions of allocative efficiency scores of rice farmers for the three production systems were presented in Table 4.19. The results revealed that mean allocative efficiency for upland rice farmers was 0.462, while the minimum and the maximum were 0.171 and 0.820 respectively. The implication of this finding is that for the average rice farmer in the upland system of production to achieve the allocative efficiency level of the most efficient rice farmer, he would have to recordedabout 54% cost saving. On the other hand, for the most cost inefficient rice farmer in the upland system to achieve the allocative efficiency score of his most efficient farmer, he would have to reducethe production cost by about 83%.

Furthermore, the result revealed that the mean allocative efficiency, minimum and maximum scores for lowland rice farmers were 0.381, 0.122 and 0.723 while for irrigated rice farmers scores were 0.514, 0.143 and 0.833 respectively. This implies that, for the

average farmer in the lowland system to achieve the allocative efficiency of his most efficient counterpart, he would have to attained about 62% cost saving. On average, allocative inefficiency in irrigated system accounts for about 49% loss in returns and represent room for improving income by increasing allocative efficiency among the irrigated farmers.

Accordingly, there is a wide scope for decreasing the cost of rice production in upland, lowland and irrigated systems by about 54%, 62% and 49% respectively without affecting the level of output. The means difference test of the allocative efficiency scores among the three systems of rice production reveals that there is no statistical significant difference in their means scores (F= 1.247 p=0.923).

Table 4.21 Frequency Distribution of the Allocative Efficiency of the rice farmers

Efficiency Scores	**Upland**		**Lowland**		**Irrigation**	
	Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**
≤ 0.29	16	17.20	29	32.58	12	12.50
0.30 – 0.49	47	50.54	42	47.19	26	27.08
0.50 – 0.69	27	29.03	12	13.48	49	51.04
0.70 – 0.89	3	3.23	6	6.74	8	8.33
≥ 0.90	-	-	-	-	1	1.04
Total	**93**	**100**	**89**	**100**	**96**	**100**
Mean	0.462		0.381		0.514	
Maximum	0.820		0.723		0.913	
Minimum	0.171		0.122		0.143	
Standard deviation	0.199		0.116		0.193	
ANOVA (F= 1.247; P= 0.923)						

4.2.3 Economic efficiency of rice production systems

Individual rice farmer's economic efficiency score was obtained using equation (3.6) which is the product of technical efficiency and allocative efficiency scores and the

frequency distributions of the resultfor the three rice production systems is depicted in Figure 7. The histogram reveals that variation in the economic efficiency scores among the rice farmers in irrigated system is relatively large, with a minimum efficiency of 0.023 (or 2.3%), and a maximum efficiency of 0.896 (or 89.6%). The mean economic efficiency among the irrigated rice farmers is below unity and it is estimated to be 0.382(or 38.2%), indicating that the irrigationrice farmers are economicallyinefficient. The analysis of the efficiency levels among the upland rice farmers reveals that a little over 46% (43) of the farmers have economic efficiency score that falls within the range of 0.21 – 0.4, while only 4 (4.3%)of the farmershave economic efficiency scores within the range of 0.81 – 1.0. The mean economic efficiency scores for the upland and lowland rice farmers are estimated to be 0.30 and 0.24 respectively. Hence, the simultaneous improvements of both technical and allocative efficiencies are necessary for the effective achievement of economic efficiency among rice farmers in all the three rice production systems.

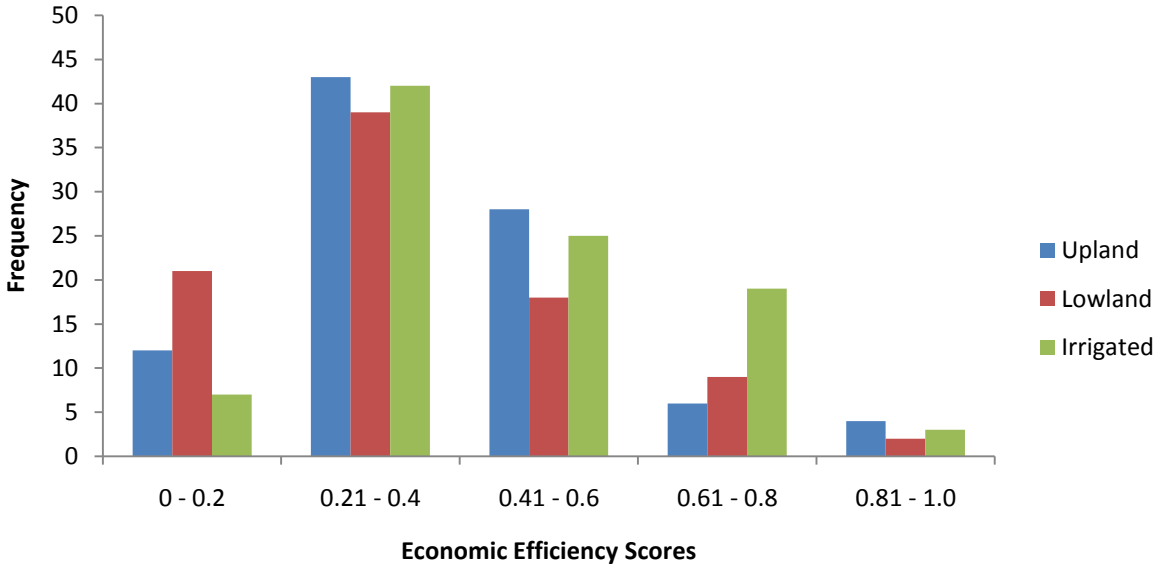


Figure 7. Frequency distribution of Economic efficiency scores of rice farmers

4.2.4 DEA efficiencies scoresof the rice farmers

The process of decomposing technical efficiency scores of rice farmers under constant returns to scale (TE_{CRS}) into scale efficiency (SE) and pure technical efficiency under variable returns to scale(TE_{VRS}) provides useful information on the direction on what to be done at farms' level and policy environmentin order for the rice production to operate at the efficient frontier level in the short and long term. The TE_{CRS} measure helps to

measure combined inefficiency effects due to both inefficiency that is due to inappropriate farm size i.e., scale inefficiency (SIE) and pure technical inefficiency (TIE_{VRS}).

The $TE_{CRS}$and TE_{VRS}scores for rice farmers in the three rice production systems were obtained using output-oriented model specified in equations (3.7) and (3.8) respectively,while the Scale efficiencies scores were obtained using the specified models in equations (3.9) and (3.11). The summary statistics and frequency distribution of the efficiencies scores are shown in Table 4.22 and 4.23 respectively. It is imperative to note that output-oriented efficiency measures deal with the question: 'By how much can rice output quantities be proportionally increased without changing the total production input quantities?'

From the results in Table 4.22, it is observed that technical inefficiencyunder constant returns to scale(TIE_{CRS}) in rice production in all the three rice systems are due to both poor input utilization (i.e., TIE_{VRS}) and failure to operate at optimal scale size (i.e., SIE). This is notedfrom the mean scores ofTE_{CRS}across the three systems of rice production which are all less than unity; 0.61for upland, 0.58 for lowland and 0.64 for irrigated systems.The average TE_{VRS}scores for the upland and lowland rice farmers has been observed to be 0.73and 0.69respectively. This implies that larger parts of the percentages of TIE_{CRS} (27%,and 31% including some deviations due to measurement errors and factors beyond farmers' control) points of the about 39%and 42% of TIE_{CRS} are due to

the farmers' failure to adopt appropriate management practices and to select correct input mixtures. The remaining percentages of TIE_{CRS}withsome deviations measured as inefficiencies(20 and 28%) are ascribedto improper scale of operations by rice farmers in the upland and lowland systems respectively. Additionally, lower mean and high standard deviation of the TE_{VRS} scores compared to SE scores in the upland and lowland systems of rice production indicate that a greater portion of TIE_{CRS} is due to TIE_{VRS}.Similar findings were reported byKumar and Gulati (2008) in India andFabio(2011) in Italia.The result shows that the TE_{VRS} scores of irrigated systems ranges between 0.32 and 1.00, with an overall mean of 0.86 while SE ranges between 0.31 and 1.00, with an overall mean of 0.72. This suggests that, if producing irrigated paddy output on the efficient frontier instead of the observed outputlevel would need to increase output averagely by 14% without changing the current quantities of inputs being used and improve scale efficiency by 28% on average.

There is no statistically significant means difference in scale efficiency scores among rice farms in the three systems of production as shown by the ANOVA result(f=1.261; p=0.145), implying that systems of production have no strong and very sensitive influences on rice farmers' scale efficiency.In terms of ranking the scale efficiency scores from highest to lowest scale efficient system is lowland, upland and irrigated system respectively.

Table 4.22: Summary statistics of the estimated efficiency measures from DEA

System	Statistics	TE_{CRS}	TE_{VRS}	Scale
Upland	Mean	0.61	0.73	0.80
	Min	0.19	0.22	0.55
	Max	1.00	1.00	1.00
	Std dev	0.27	0.23	0.15
	Mean Inefficiency (%)	39	27	20
Lowland	Mean	0.58	0.69	0.81
	Min	0.14	0.17	0.51
	Max	1.00	1.00	1.00
	Std dev	0.28	0.25	0.11
	Mean Inefficiency (%)	42	31	19
Irrigation	Mean	0.64	0.86	0.72
	Min	0.16	0.32	0.31
	Max	1.00	1.00	1.00
	Std dev	0.36	0.17	0.28
	Mean Inefficiency (%)	36	14	28
ANOVA for scale	(F=1.261 p=0.145)			

4. 2.4.1*Returns to scale*

Table 4.23 provides the frequency distribution of the nature ofreturns toscale for the three systems of rice production. The results indicate that about 22% and 27%of the upland and lowlandrice farmers respectively are operating at most productive scale size andexperiencing constant returns to scale (CRS) while only about13%of the irrigated rice farmers are operating at CRS. On the other hand,about 62% of irrigated rice farmers are operating below theiroptimal scale size and thus, experiencing increasing returns to scale (IRS),this implies that these farmers can enhance TE_{CRS} by increasing their operationalsize. As observed in the table, about 38% andover 34% of upland andlowland ricefarmersrespectively have been noticedto be operating in the zone of decreasing returnstoscale (DRS) and,thus, downscalingseems to be an appropriate strategic option for these farmers intheir pursuit to optimise their production output. On a general note,IRS isseemto be the most importantform of scale inefficiency in all the three rice production systems considered in the study.

Accordingly, these results suggest that scale inefficiency is mainly due to the farmers operating below the optimal scale.The underlying rationale is that the rice production is mainly characterised by a large number of small-sized farms (Table 4.2) that generally face many productionconstraints (Table 4.37). These farmersare usually constrained by inadequate credit facilities, high cost of inputs, marketing problems, low output prices, poor implementation ofrice sector policiesimpede them from reaching their optimum size. Cadoni and Angelucci (2013)stressed that production constraints are among the

main factors that usually obstructattainment of efficient scales by part of the rice farmers in Nigeria.

Table 4.23 Frequency distribution of rice farmers operating under constant, increasing and decreasing returns to scale

	Upland		Lowland		Irrigation	
Returns to Scale	**Frq**	**%**	**Frq**	**%**	**Frq**	**%**
CRS	20	21.5	24	27.0	12	12.5
IRS	38	40.8	35	39.3	59	61.5
DRS	35	37.6	30	33.7	25	26.0
Total	**93**	**100**	**89**	**100**	**96**	**100**

Note: Frq stands for frequency

4.2.4.2*Relationship between scale efficiency scores and farmers' farm sizes*

Farm size was found to be negative and significant variable in influencing rice farmers' technical and allocative inefficiencies (Tables 4.24 and 4.25 respectively) across the three production systems.In this regards, a relationship of rice farmers' farm size and their scale efficiency scores was established and the result is depicted in figure 8. The figure revealed positive slopes and direct relationship between the farm sizes and scores of scale efficiency for the farmers in the three systems of production. This suggests that relatively large-sized farms tend to have, as expected, higher scale efficiency score than small-scale farms. This finding is in line with the result of Fabio (2011)who observed that the larger and less fragmented citrus farms in Italy tend to show higher scale efficiency scores.

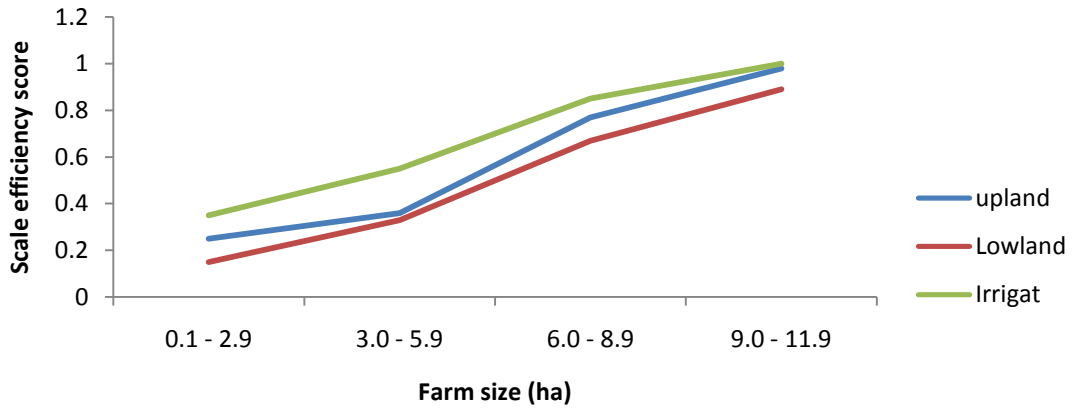


Figure 8 Relationship between farmers' farm size and scale efficiency scores

4.3 Sources of Inefficiencies Differential in Rice Production

4.3.1 Technical inefficiency effects model

Social, economic, demographic and institutional factors are hypothesized to have influences on the rice farmers' technical efficiencies in all the three systems of production. Adopting the specification of the model (3.3), an attempt was made to ascertain the sources of technical inefficiency differential among rice farmers across the three rice production systems. The coefficients of the exogenous variables in the technical inefficiency model are of particular interest in terms of making policy options for performance improvement. As a rule, a negative sign on an inefficiency parameter means that the variable reduces technical inefficiency, while a positive sign increases technical inefficiency. Results of the maximum likelihood estimation of the inefficiency model for the three rice production systems are summarized in Table 4.24.

Out of the ten exogenous variables that explained technical inefficiency variable seven were statistically significant and carried the expected signs. The age of the farmers, years of rice production experience, years of schooling, number of extension visits on rice production practices in the surveyed season, years spent as member in farmers' cooperative, amount of credit used on rice farm and farm size were significant factors found to explaintechnical inefficiency in rice production in the study areas.

The variable age of the farmers is positive and statistically significant at 1%, 5% and 5% levels in upland, lowland and irrigated systems of production respectively. This suggests that younger farmers are more efficient than the older ones across the three production systems. The reason for this is probably because the age variable picks up the effects of

physical strength as well as farming experience of the farmer. Although farmers become more skillful as they grow older, the learning by doing effect is attenuated as they approach older age, as their physical strength starts to decline. This finding is consistent with study by Amaza and Maurice (2005) in which they found that age of rice farmers was a good determinant that decreases technical inefficiency and concluded that younger farmers were more efficient than the older ones. Also, Awotide *et al.* (2010) observed that age of rice farmers in Nigeria is positively correlated with the rate of adoption of improved rice technology which invariably increases the efficiency level of the farmers.

The variable years of schooling is used as proxy for managerial input. Increased farming experience coupled with higher level of educational achievement may probably lead to better assessment of the importance and complexities of good farming decision, including efficient use of production inputs. Results suggest that years of schooling and years of experience in rice production across the three production systems are negative and statistically significant determinants of a farmer's technical efficiency. Years of schooling reduces inefficiency significantly at 1%, 10% and 5% levels in upland, lowland and irrigated system of production respectively. The years of experience increases efficiency significantly at 10% across the three rice production systems. Similar findings was reported by Saka and Lawal (2009) in which theynoted that more educated rice farmers are more likely to be efficient as compared to the less educated counterparts as a result of their better access to information and experience as well as good farm planning and high rate of adoption.

Amount of credit variable was used to capture the effect of credit usage on the technical efficiency of the rice farmers. It is assumed that the availability of credit soften the constraints of high prices of modern production inputs, facilitating timely access of inputs and hence is supposed to increase the technical efficiency of the farmers. In line with this assumption, the variable is found to be negative and statistically significant at 1%, 5% and 10% levels in upland, lowland and irrigated systems respectively. This suggests that availability and accessibility of credit is an important factor for achieving a higher level of technical efficiency. The finding is consistence with that of Usman and Suleiman (2010) who noted that technically inefficient farmers can possibly get more efficient in the short run by facilitating their access to credit.

The number of extension visits and years spent as member of cooperative variables show the expected negative signs and are statistically significant determinants of technical efficiency across the three production systems. The decreased inefficiency level with more number of extension visits and more years of farmers' cooperative membership were most probably due in large part adopting the improved and recommended practices of rice production brought to them by extension officers individually or through the farmers' cooperatives. This result agrees with the finding of Jirgi *et al.* (2009), who observed that extension visit reduces technical inefficiency and increases farmers' productivity among rice farmers in Niger State, Nigeria.

Table 4.24Determinants of technical inefficiency of the rice farmers

	Upland	**Lowland**	**Irrigation**
Variables	**Coefficient**	**Coefficient**	**Coefficient**
Constant (Z_0)	0.452 (0.400)	0.635 (0.775)	0.490 (0.700)
Age (Z_1)	0.054 (0.014)*	0.038 (0.016)**	0.008 (0.003)**
Farming experience (Z_2)	-0.038 (0.021)***	-0.008 (0.004)***	-0.009 (0.005)***
Years of schooling (Z_3)	-0.055(0.017)*	-0.024(0.014)***	-0.017 (0.008)**
Household size (Z_4)	0.036 (0.025)	0.121 (0.077)	0.015 (0.036)
Distance to seed market (Z_5)	0.008 (0.033)	0.038 (0.097)	0.035 (0.126)
Extension visit (Z_6)	-0.019 (0.003)*	-0.111 (0.051)**	-0.024 (0.009)*
Years in farmers' cooperative (Z_7)	-0.008 (0.001)*	-0.025 (0.012)**	-0.010 (0.004)**
Amount of credit (Z_8)	-0.004 (0.001)*	-0.532 (0.264)**	-0.009 (0.005)***
Farm size (Z_9)	-0.010 (0.004)**	-0.023 (0.012)***	-0.019 (0.007)*
Tenancy (Z_{10})	0.349 (0.206)	0.164 (0.230)	0.083 (0.113)
Sample size	93	89	96

Note: * significant at 1% level, ** significant at 5%, *** significant at 10%.
Figures in parentheses are the standard errors

4.3.2 Sources of allocative efficiency in rice production

The result of the maximum likelihood estimates of the parameters of the allocative inefficiency function (equation 3.4) for the three rice production systems is presented in Table 4.25. As a general rule in interpreting results of inefficiency function, a negative coefficient indicates reduced farm allocative inefficiency and, hence, increased allocative efficiency and a positive coefficient of a parameter the reverse is the case. The socioeconomic factors included in the allocative inefficiency model were age of farmer, years of rice farming experience, years of schooling, household size, distance to seed market, number of extension visits, years of membership in farmers' cooperative, amount of credit used on rice farms, farm size and tenancy. The results reveal that, among the included variables, years of rice farming experience, years of schooling, number of extension visits, years of membership in farmers' cooperative and farm size are found to

be generally significant determinants of allocative inefficiency in all the three rice production systems (Table 4.25).

Years of schooling and years of rice farming experience were negative and significantly related to the farmers' allocative inefficiency both at 5% level in upland system, 1% level in lowland and irrigated systems. More educated and experienced farmers are usually equipped with the ability and expertise to combine resources in an optimal way given the prices of available technology and so they can curtail wastage in the use of production resources. Similar results were reported by Latifat *et al.* (2013), Ogundari and Ojo (2007) and Audu *et al*. (2013), in which they all observed the significant impact of education and farming experience on reducing farmers' allocative inefficiencies.

Years of membership in farmers' cooperative and number of extension visits were negatively related to the farmers' allocative inefficiency and were both significant at 1% level in upland system and 5% levels and irrigated system of production while the two variables were both significant at 10% level in lowland systems of rice production. Years spent as member in farmers' cooperative and high frequency of extension visits increase farmers' chances of knowledge and awareness about rational and efficient allocation of production resources and facilitate the rate of adoption. This finding is consistent with a study of Ogundari and Ojo (2007) among small scale food crop farmers in Nigeria.

Table 4.25. Maximum likelihood estimates of the determinants of allocative efficiency in rice production

Variables	Upland Coefficient	Lowland Coefficient	Irrigation Coefficient
Constant (Z_0)	0.128(0.484)	0.152(0.622)	0.457(0.673)
Age (Z_1)	0.004(0.010)	0.013(0.008)	0.004(0.018)
Farming experience (Z_2)	-0.019(0.010)**	-0.042(0.012)*	-0.063(0.022)*
Years of schooling (Z_3)	-0.017(0.009)**	0.018(0.007)*	0.097(0.033)*
Household size (Z_4)	0.027(0.030)	0.03(0.020)	0.036(0.031)
Distance to seed market (Z_5)	-0.136(0.108)	0.120(0.105)	0.234(0.194)
Extension visit (Z_6)	-0.094(0.030)*	-0.02(0.011)***	-0.006(0.003)**
Years in farmers' cooperative (Z_7)	-0.025(0.009)*	-0.027(0.016)***	-0.006(0.003)**
Amount of credit (Z_8)	-0.003(0.010)	-0.061(0.039)	0.002(0.001)
Farm size (Z_9)	-0.025(0.015)***	-0.121(0.056)**	-0.016(0.005)*
Tenancy (Z_{10})	-0.429(0.383)	-0.365(0.245)	-0.112(0.110)
Sample size	93	89	96

Note: * significant at 1% level, ** significant at 5%, *** significant at 10%.
Figures in parentheses are the standard errors

4.3.3Tests of hypotheses

The generalized likelihood test ratios are performed using the specified equation (3.1) to test the first three hypotheses for the study and the results of the testing are shown in Table 4.26. The first null hypothesis states that rice farmers in the three production systems are not operating on the technically efficient frontier i. e.

$$H_0: \gamma \neq 0$$

The one-sided generalized likelihood ratio tests of alternative hypothesis $\gamma = 0$, is automatically tested and result generated by Frontier 4.1software. The test provided estimates of 39.71, 71.08, and 38.86 for upland, lowland and irrigated frontiers respectively distributed as mixed chi-squared. At 14 degree of freedom, theseestimates are found to be statistically significant at 1% levels, indicating that the average production function is not a suitable specification of rice production in the three systems and technical inefficiency effects are not random errors. Therefore, the null hypothesis of rice farmers in the three systems of production are not operating on the technically efficient frontieris strongly accepted.

The second null hypothesis states that the socioeconomic characteristics of rice farmers have no effect on the technical efficiency of rice farmers in all the three systems of production i. e.

$$H_0: u_i = \delta_1 = \delta_2 = \cdots\cdots\cdots\cdots = \delta_{10} = 0$$

The log-likelihood function estimates of the traditional response models for the upland, lowland and irrigation were 32.11, 27.28 and 32.71 and with the inefficiency effects were 54.23, 46.67 and 61.35 respectively. In accordance with the specified equation (3.5), the differences of these two estimates in each system multiply by -2 yieldedλ values of 44.24 for upland, 38.78for lowland and 57.28for irrigated system. The estimated values of λare found to be statistically significant at 1% levels at 10 degree of freedom. Hence, the null hypothesis that socio-economic characteristics of rice farmers have no effect on technical inefficiency is decisivelyrejected for all the systems. This result confirms that the common influence of the included socio-economic variables on the levels of technical inefficiency is statistically significant.

Also, using the equation (3.5), the result of the generalized likelihood ratio test of the third hypothesis that states the stochastic production frontiers for all the rice production systems are the same is revealed in Table 4.26and the null hypothesis is specified as

$$H_0: \gamma = \beta_{k_1} = \beta_{k_2} = \beta_{k_3} = k$$

The value of the log likelihood function for the stochastic frontier estimated by pooling the data for all the three rice production systems is 321.69while the sum of the values of the log-likelihood functions for the three stochastic production functions is 162.25. The difference of these two values multiply by -2 gives lambda value of -318.88and it was found to be statistically significant at 1% levels at 10 degree of freedom, which implies that the null hypothesis is strongly rejected.

Theimplication of this finding is that the three rice production system frontiers cannot be pooled together,showing that there are significant differences in the input parameters, technical efficiency scores and random variations across the three rice production systems. It is anindication that differences exist in the production technology and environment andtherefore, the stochastic frontiers for rice farmers in upland, lowland and irrigation are not the same and that any efficiency comparison across these three samples should be performed with respect to the metafrontier estimates instead of the pooled stochastic frontier.

Table 4.26Hypothesis testing for stochastic production frontier models

Null Hypotheses	**LR test statistic**	**Degree of freedom**	**χ^2 Critical**	**Decision**
Upland				
$H_0; \gamma \neq 0$	39.71	14	29.14	Accept H_0
$H_0: u_i = \delta_1 = \delta_2 = \cdots\cdots = \delta_{10} = 0$	44.24	10	23.21	Reject H_0
Lowland				
$H_0; \gamma \neq 0$	71.08	14	29.14	Accept H_0
$H_0: u_i = \delta_1 = \delta_2 = \cdots\cdots = \delta_{10} = 0$	38.78	10	23.21	Reject H_0
Irrigated				
$H_0; \gamma \neq 0$	38.86	14	29.14	Accept H_0
$H_0: u_i = \delta_1 = \delta_2 = \cdots\cdots = \delta_{10} = 0$	57.28	10	23.21	Reject H_0
Poolability of the systems'frontiers				
$H_0: \gamma = \beta_{k_1} = \beta_{k_2} = \beta_{k_3} = k$	-318.88	14	29.14	Reject H_0

4.4 Estimation of Stochastic Metafrontier Model

Differences in the estimated parameters in the three rice system frontiers are indicative of discrepancies in the use of production technology among the rice farmers. This has already been confirmed by the poolability test shown in Table 4.26 and this rationalises the computation of metafrontier model. Using parameter estimates from the system

frontiers (Table 4.15), a linear programming optimization model (equation 3.19) is solved for the entire sample using translog specification for the metafrontier model (equation 3.1). Estimation of the metafrontier was done using SHAZAM software adopting with some modifications the codes in O'Donnell *et al*. (2008) (Appendix 9). The technology gap ratio (TGR) and the technical efficiencies in relation to the metafrontier function areestimated and discussed. The analysis of technical efficiency using stochastic metafrontier model gives a better overview of the comparability of technical efficiency scores across the three rice production systems.

4.4.1 Parameter estimates of pooled stochastic frontier and metafrontier models

The single-stage maximum likelihood procedure of the Frontier 4.1 (Coelli, 1996) was used to estimate the parameters of the stochastic frontier for the pooled data (see Appendix 5 for the full computer result) while the parameter estimates of the metafrontier was obtained using SHAZAM software. The parameter estimates of the pooled stochastic frontier model and metafrontier model are revealed in Table 4.27. In the diagnostic parameters of the pooled model, the value of γ (0.676)is statistically significant at the 1% level, implying that about 68% of random variation in rice production is explained by inefficiency. The mean technical efficiency of the pooled sample isabout 65%. Thus, in a short run, there is a scope for increasing rice production by 35%, by adopting the technology and techniques used by the best rice farmers.

As shown in the pooled stochastic frontier result, all the first order variables have positive and significant effects on the rice output with the exception of cost of irrigation/water management which is positive but insignificant at 10% level. Most of the interaction terms (second order variables) were statistically significant at varying levels of significance, implying the suitability of the specified functional form of translog. Among the second order variables, the coefficient of squared terms for seed, fertilizer and those of interactions of seed/labour and seed/fertilizer are positive and significant at 5% levels,while labour/fertilizer and fertilizer/irrigationare positive and significant at 10% levels, indicating interactivelya direct relationship with total rice output.

Table 4.27.Parameter estimates for the translog stochastic production frontier models and Meta frontier

Variables	**Pooled frontier**			**Meta frontier**
	Coefficient	**Stand Err**	**t value**	**Coefficient**
$Constant\ (\beta_0)$	9.749*	3.134	3.110	32.167
$lnseed\ (\beta_1)$	0.103**	0.021	4.875	3.228
$lnlabour\ (\beta_2)$	0.774***	0.418	1.853	4.771
$lnfertilizer\ (\beta_3)$	0.273*	0.096	2.838	2.119
$lnirrg\ (\beta_4)$	0.806	0.572	1.410	0.366
$lnseed^2\ (\beta_5)$	0.462**	0.210	2.206	0.121
$lnlabour^2\ (\beta_6)$	0.685	0.535	1.279	0.028
$lnfertilizer^2(\beta_7)$	0.443**	0.192	2.300	0.336
$lnirrg^2\ (\beta_8)$	0.149	0.172	0.865	0.242
$lnseed \times lnlabour\ (\beta_9)$	0.215**	0.098	2.194	0.097
$lnseed \times lnfertilizer\ (\beta_{10})$	0.558**	0.280	1.992	0.128
$lnseed \times lnirrg\ (\beta_{11})$	0.278	0.336	0.828	1.457
$lnlabour \times lnfertilizer\ (\beta_{12})$	0.006***	0.003	1.720	0.776
$lnlabour \times lnirrg\ (\beta_{13})$	0.041	0.028	1.458	0.219
$lnfertilizer \times lnirrg\ (\beta_{14})$	0.110***	0.060	1.819	0.536
Variance Parameter				
Sigma-squared	0.598*	0.051	11.785	
Gamma	0.676*	0.196	3.442	
Log-likelihood	321.69			

Mean Efficiency	0.647	
Sample size (n)	278	278

Note: * significant at 1% level, ** significant at 5%, *** significant at 10%.

4.4.2 Metafrontier technical efficiencies and technology gap ratios

The parameters of the metafrontier obtained (Table 4.27) are used in the computation of technology gap ratios and technical efficiency relative to the metafrontier as shown in equations (3.16) and (3.18), respectively. Table 4.28 reports the summary statistics of the technology gap ratios (TGR), along with the relative technical efficiency to the stochastic frontier for the three rice production systems (TE) and the metafrontier efficiency score (TE*). However, the system-specific technical efficiency scores (TE) cannot be compared across systems since they are estimated with respect to different frontiers and therefore, comparisons should only be based on estimates from the metafrontier. The TGR is the mean gap between the metafrontier (the common technology) and the system frontier (system technology) and its ranges from 0 to 1 with a value of 1 indicating that the system frontier is tangent to the metafrontier (Battese *et al*., 2004).Thus, it is possible for farmers within systems to attain efficiencies under the common technology of the metafrontier.

The mean values for the TGR for upland, lowland and irrigated systems are 0.446, 0.377 and 0.538 respectively. This implies that irrigation farmers produce, on the average, about 54% of the potential output given the technology available to the rice production systems used for this study**.** Conversely, farmers in lowlandsystem produce averagely only about 38% of the potential output given the metatechnology available and therefore require about 62% increase in output before operating on the metafrontier. The maximum

TGR value of unity for the irrigated system indicates that the system stochastic frontier istangent to the metafrontier (Figure 9). But the maximum value of 0.933 for Upland and 0.876 for lowland system show that they are lower to metafrontier. This implies that farmers in upland and lowland systems are far away from the potential output that was obtained by the metafrontier function. Ayinde *et al.* (2009) reported an overall average of varietal TGR for rice farms in Nigeria as 0.85 for the three important varieties used by rice farmers.

The dispersion of technical efficiencies (TE*) scores for a particular system around the system-specific mean TE* is captured by the standard deviation. The standard deviations of the TE* for the upland, lowland and irrigated systems are 0.256, 0.267 and 0.163while their respective mean TE* scores are 0.311, 0.241 and0.410in that order. This indicates that the irrigated rice farmers achieved the highest mean TE* (0.410) with lowest dispersion of the population scores around the mean (0.163) while the lowland farmers had the lowest mean TE* (0.241) with highest standard deviation (0.267). The implication of this finding is that given the rice production technology potentially available to all systems, irrigation farmers produce about 41% of potential output, whereas lowland farmers produce only 24% of potential output on average. Lowland farmers can increase their output by up to 76%, if the potential technology available to all systems, the technology corresponding to the metafrontier, is adopted by such farmers.

Table 4.28Summary statistics of the estimates of technical efficiencies and technology gap ratios

System	Statistics	System TE	TGR	Meta frontier TE*
Upland	Mean	0.643	0.446	0.311
	Min	0.161	0.029	0.011
	Max	0.958	0.933	0.891
	Std dev	0.181	0.324	0.256
Lowland	Mean	0.622	0.377	0.241
	Min	0.130	0.019	0.003
	Max	0.856	0.876	0.761
	Std dev	0.159	0.241	0.267
Irrigation	Mean	0.734	0.538	0.410
	Min	0.162	0.053	0.010
	Max	0.986	1.000	0.953
	Std dev	0.260	0.225	0.163

Figure 9 illustrates results presented in Table 4.28. In the same graphic are presented system-based frontier curves of the three rice production systems and the metafrontier curve. The inefficiency levels areindicated by the distance between the production point and the frontier curve, while thetechnology gap ratios are represented by the distance between the system-based and themetafrontier curve.

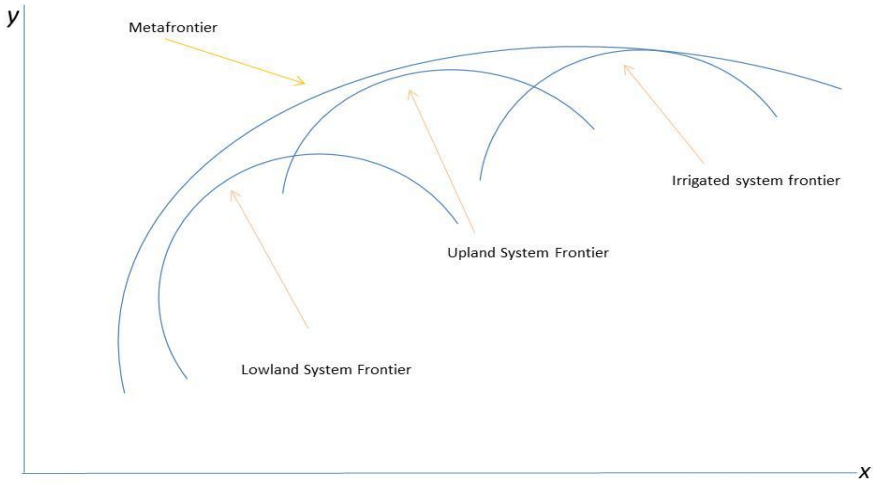


Figure 9: Graphical representation of the performance of rice production systems

4.4.3 Distributions of TGRs for differentrice production systems

The frequency distributions of the TGRs for the rice production systems might provide a clear picture and better perception about the heterogeneity of production technology among the rice farmers in the study areas. Figure 10 shows that there is wide variability in TGRs for rice production systems in the sampled rice farmers. As shown on the figure, farmers in upland and lowland systems tend to have skewed frequency distributions of the TGRs to the left because about 72% and over 62% of the farmers respectively have TGRs of less than 0.46. The lowland system contains a larger number of rice farmers with lower TGRs. Farmers under irrigated system of rice production are inclined to have symmetrical frequency distributions of the TGRs, centered at around 0.5 as more than half of the farmers(49 farmers) hadTGR fall withinthe range of 0.46–0.65. It can be deduced that a system with a symmetrical distribution of TGRs perform better as compared with a system with a proportionately skewed distribution of TGRs to the left, probably because of more experience, more extension contact, higher years of schooling (Table 4.14) which invariably enhance likelihood of advanced technology adoption. This finding agrees with the finding of Saka and Lawal (2009) who reported that rice farmers in southwestern Nigeria were using less productive and labour extensive technology in rice production resulting to a very wide gap from achieving the frontier output of about 3.6tonnes of paddy per hectare.

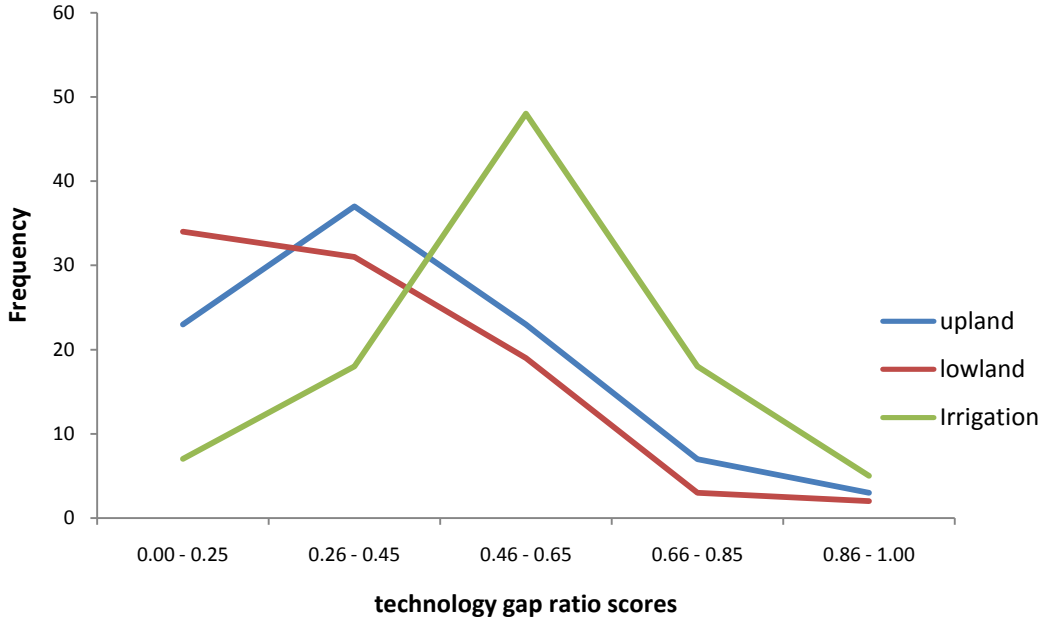


Figure 10 Frequency distribution of technology gap ratios

4. 5.The Policy Analysis Matrix (PAM)

In this section, the PAM framework was used for the data analysis and the results obtained from the application of PAM revealed the levels of profitability and divergences in the three rice production systems as shown in Table 4.35.The PAM method was specifically applied in this study to assess the level of competitiveness of rice production systems and the comparative advantage.The basic information required in the PAM were the physical quantities of inputs and paddy output of rice production systems, private prices and budget, parity prices for milled rice output and tradable inputs and social prices and budget and these were obtained as follows:

4.5.1 Inputs and paddy output of rice production systems

In accordance with Monke and Pearson (1989), the production inputs were disaggregatedinto traded and non-traded (domestic) inputs. The observed on-farm activities in rice production included land preparation, planting, thinning, weeding, fertilizing, controlling pest and disease, irrigation and water management, harvesting, threshing, winnowing, bagging and transportation (Table 4.29). These activities were either carried out by family labour, hired labour orboth family and hired labour (Table 4.6).The unit of measurement forhuman labour quantities istotal man-day[1] utilized in performing the farm operations.Most of these on-farm operations were predominantly carried out by family and hired combination source of human labour in the rice production. This result confirmed the finding in Table 4.6 in which about 56% of the rice

[1] One man-day is equivalent to 5 working hours of adult man

farmers reported to have used both family and hired labour.The total labour used by upland, lowland and irrigated rice farmers were 34.2, 36.1 and 39.7 man-day/ha respectively(Table 4.29).

Table 4.29 Pattern of human Labour use on rice farms in the study areas

Field operation	**Source of labour**	**Rice production systems**					
		Upland		**Lowland**		**Irrigated**	
		Hours	**Manday**	**Hours**	**Manday**	**Hours**	**Manday**
Land preparation	Family	10	2	15	3	15	3
	Hired	25	5	5	1	12.5	2.5
Planting	Family	10	2	20	4	20	4
	Hired	5	1	2	0.4	5	1
Thinning/transplanting	Family	20	4	25	5	10	2
	Hired	-	-	3	0.6	5	1
Weeding	Family	5	1	16	3.2	15	3
	Hired	10	2	5	1	5	1
Fertilizing	Family	15	3	10	2	10	2
	Hired	-	-	5	1	5	1
Pests and Diseases	Family	20	4	20	4	20	4
control	Hired	-	-	-	-	-	-
Irrigation/water	Family	-	-	-	-	25	5
management	Hired	-	-	-	-	10	2
Harvesting	Family	5	1	6.5	1.3	10	2
	Hired	10	2	15	3	5	1
Threshing	Family	5	1	3	0.6	2	0.4
	Hired	5	1	5	1	3	0.6
Winnowing	Family	4	0.8	4	0.8	3	0.6
	Hired	5	1	4	0.8	2	0.4
Bagging	Family	3	0.6	4	0.8	3	0.6
	Hired	4	0.8	3	0.6	3	0.6
Transportation	Family	10	2	10	2	10	2
	Hired	-	-	-	-	-	-
Total Labour	Family	107	21.4	133.5	26.7	143	28.6
	Hired	64	12.8	47	9.4	55.5	11.1
Grand total		**171**	**34.2**	**175.5**	**36.1**	**198.5**	**39.7**

Note: Five working hours of adult man is equivalent to one man-day

From the Table 4.30, the surveyed rice farmers used inorganic fertilizers, such as NPK and Urea, even though the average quantities appliedwas below the recommended rate of about 200kg (4 bags) of NPK/ha and 125kg (2.5 bags) of Urea for a hectare (Ekeleme*et al*., 2008).The combined average quantities of fertilizer applied by upland, lowland and irrigated rice farmers were 1.8, 1.9 and 2.0 bags/ha respectively. On average basis,the quantities of seed used by the sampled farmers under upland, lowland and irrigated systems were 27kg/ha, 25kg/ha and 38kg/ha respectively. And these average seeds quantities are below the recommended seed rate of about 50kg/ha given by Ekeleme *et al.* (2008), implying that the quantities of seed used by the sampled rice farmers were under dosed.The paddy yield is higher in irrigated system (3174.1kg/ha) followed by lowland (2170.5kg/ha) and upland (1989.6kg/ha). The higher yield obtained by irrigated farmers may be attributed to the more quantities of fertilizers and seeds used by the farmers when compared to the quantities applied by the farmers from the two other systems.

A conversion factor for paddy rice output (parboiled) into milled rice output at the three different study sites was developed and tested. The conversion factors were tested at different locations in the study areas and were observed to be effective, reliable and yielded constant results. For the upland, lowland and irrigated systems the conversion factors were 0.47, 0.42 and 0.49 respectively. All things being equal, this implies that the paddy output of upland, lowland and irrigated systems of parboiled paddy will produce about 935.11kg, 911.61kg and 1555.31kg/ha of milled rice output respectively.The lowest conversion factor of 0.42 recorded for the lowland was mainly due to the problems of empty rice panicle as a result of low water at milking stage and blast. These problems were not very much pronounced in irrigated and upland rice farming systems in the surveyed season.

Table 4.30 Physical Quantities of Inputs and rice outputfor the production systems

	Rice production systems		
Input/output items	**Upland**	**Lowland**	**Irrigation**
Tradable Inputs			
Fertilizer (kg/ha)	90	95	100
Seeds (kg/ha)	27	25	38
Agrochemicals (liters/ha)	60	75	55
Domestic Inputs			
Labour (manday/ha)			
Hired labour	12.8	9.4	11.1
Family labour	21.4	26.7	28.6
Irrigation/Management (₦/ha)			
Depreciation Water pump/Siphon	-	-	265
Fuel	-	-	830
Water charges/season	-	-	600
Other items (₦/ha)			

Bags	1100	1100	1100
Depreciation (Drum, Tarpaulin, Bowl, Sickles, hoes, cutlass)	780	780	780
Parboiling and Milling (₦/45kg)	165	165	165
Output (kg/ha)			
Paddy yield (kg/ha)	1989.6	2170.5	3174.1
Milled conversion factors	0.47	0.42	0.49
Milled Equivalent (kg/ha)	935.11	911.61	1555.31

4.5.2. Private prices and budget

Table 4.31 shows the private prices of the inputs and output alongside with private farm budgets for the three rice production systems. The private prices arethe prevailing actual market prices obtained during the field interviews with farmers. The average wage rate for hired labour was ₦850/man-day andthis wage rate was used as opportunity cost to assess the private costs offamily labouremployed on the rice farms. Averagely, the prices of seeds and fertilizers across the rice systems were₦690/kg and ₦5,500 per 50kg bag (i.e. ₦110/kg) respectively. At the farm gate, the average prices for milled rice produced under the three systems at the time of the survey were found to be the same at ₦190/kg of milled rice.The private budget is therefore obtained by multiplying the physical quantities of input-output (Table 4.30) by the respective private prices in Table 4.31.

Table 4.31 Private Prices and budgets for the three Rice Production systems

System	Input/output items	Private Data	
Upland	**Tradable Inputs**	**Prices**	**Budget (₦)**
	a) Fertilizer	1100 (₦/kg)	99,000
	b) Seeds	690 (₦/kg)	18,630
	c) Agrochemicals	100(₦/litr)	6,000
	Domestic Inputs		
	i. Total Labour	850 (₦/manday)	29,070
	ii. Depreciation (drum, tarpaulin, bowl, sickles, hoes, cutlass)	780	780
	iii. Bags	1,100	1,100
	iv. Parboiling and Milling	165 (₦/45kg paddy)	7,295.2
	Milled yield (Revenue)	190 (₦/kg)	177670.9
Lowland	**Tradable Inputs**		
	a. Fertilizer	1,100 (₦/kg)	104,500
	b. Seeds	690 (₦/kg)	17,250
	c. Agrochemicals	100(₦/litr)	7,500
	Domestic Inputs		
	1. Total Labour	850 (₦/manday)	30,685
	2. Depreciation (drum, tarpaulin, bowl, sickles, hoes, cutlass)	780	780
	3. Bags	1,100	1,100

	4. Parboiling and Milling	165 (₦/45kg paddy)	7,910.3
	Milled yield (Revenue)	190 (₦/kg)	166,824.6
Irrigated	**Tradable Inputs**		
	a) Fertilizer	1,100 (₦/kg)	110,000
	b) Seeds	690 (₦/kg)	26,220
	c) Agrochemicals	100(₦/litr)	5,500
	Domestic Inputs		
	i. Total Labour	850 (₦/manday)	33,745
	ii. Irrigation/Management	1,695	1,695
	iii. Depreciation (drum, tarpaulin, bowl, sickles, hoes, cutlass)	780	780
	iv. Bags	1,100	1,100
	v. Parboiling and Milling	165(₦/45kg paddy)	11,638.4
	Milled yield (Revenue)	190 (₦/kg)	295,508.9

4.5.3. Parity prices for milled rice output and tradable inputs

The parity price for milled rice is shown in Table 4.32while for the tradable inputs parity prices are presented in Tables 4.33and 4.34.The computational procedures for estimating the parity price for milled rice involves evaluating the price of rice at a port of entry and adjusting it for other costs like transportation cost, handling, marketing and transaction costs that are incurred in the process of bringing the milled rice to the study sites. Policy effects such as taxes, subsidies and tariffs on the rice are also included in these adjustments. The import parity price for rice began with the free on board (FOB) price at the Brazil port and ended with the social price at the farmers' level in the study areas. The FOB price in the Brazil, US$ 442/ton, was used as the reference price because most (about 70%) of the polished rice imports into Nigeria come fromBrazil(Cadoni and Angelucci, 2013). The cost of insurance and freight (CIF) from Brazil to Nigeria was US$ 30/ton, and the exchange rate was ₦157/US$1. With these parameters, theCIF price in Nigeria was therefore calculated to be equals to₦74.1/kg.The parity pricereflects the cash or financial value of the milled rice at farm gate and at the time of the survey it is found to be about 1.06$/kg (Table 4.32).

Table 4.32. Import Parity Price for Milled Rice in Nigeria

S/No	Items	
1	FOB Price (US$/ton) in the Brazil	442

2	Freight and Insurance (US$/ton)	30
3	CIF Price (US$/ton)	472
4	Exchange Rate (₦/US$)	157
5	CIF Price (₦/kg)	74.1
6	Tariff, transportation and handling (kg):	
	a) Import tariff (35%)	25.9
	b) Port to study sites (mean ₦/kg)	21.5
	c) Handling (₦/kg)	24.5
7	Import parity at wholesale (₦/kg)	146
8	Distribution cost to farm gate (₦/kg)	19.8
9	Import parity value at farm gate (₦/kg)	165.8

Sources: For the FOB "parboiled rice 100%" **http://www.riceauthority.com/prices/**

The import parity prices for tradable inputs (fertilizer, seeds and agrochemicals) which are also required for computation of social prices and thus the social budget for the three rice production systems is shown in Table 4.33 for fertilizer and seeds and Table 4.34 for the agrochemicals.From the Table 4.33, the social prices for fertilizer and seeds are calculated to be ₦923.3/kg and ₦540/kg respectively. The main sources of fertilizer importsinto Nigeria are the Black Sea and the Baltic Sea and the CIF is US $311.7/tonne (Fuentes*et al.*, 2012).

Table 4.33. Import Parity Prices for fertilizer and seeds for Rice Production

S/No	Items	Fertilizer	Seeds
1	CIF Price (US$/ton)	311.7	1057.3
2	Exchange Rate (₦/US$)	157	157

3	CIF Price (₦/kg)	48.9	166
4	Transportation, handling and storage (₦/kg)		
	a) Port to study sites (mean)	135.6	125
	b) Handling and storage	125.5	135
	c) Import subsidy (25%)	12.2	10.0
5	Export parity at wholesale (₦/kg)	297.8	416
6	Distribution cost to farm gate (₦/kg)	125.5	124
7	Import parity value at farm gate (₦/kg)	923.3	540

According to Amaka (2013) the main source of agrochemicals import into Nigeria is India. About ₦1.45bn worth of agrochemicals was imported into the country in 2013 by the Indian Basic Chemicals, Pharmaceutical and Cosmetics Export Promotion Council (CHEMEXCIL).The Table 4.34 shows the import parity price for agrochemicals (pesticides and insecticides) used in rice production.

Table 4.34. Import Parity Price for Agrochemicals for Rice Production

S/No	Items	Agrochemicals
1	CIF Price (US$/KL)	350.3
2	Exchange Rate (₦/US$)	157
3	CIF Price (₦/litr)	55
4	Transportation, handling and storage (₦/litr)	
	a) Port to study sites (mean)	7.5
	b) Handling and storage	12.5
	c) Import subsidy (25%)	5
5	Export parity at wholesale (₦/litr)	70
6	Distribution cost to farm gate (₦/litr)	15
7	Import parity value at farm gate (₦/litr)	85

4.5.4 Social prices and budget

The social budget is calculated by multiplying tradable inputs, domestic factors, and output in the input-output table (Table 4.30) by their respective social prices (Tables4.32, 4.33 and 4.34). The summations of all the costs of tradable and domestic inputs were ₦102,777 and ₦87,203.6 for upland system and ₦117,525 and ₦48,958.4 for irrigated system respectively. In terms of ranking of the average gross revenue earned by the farmers in the three systems the irrigated system is ranked the first followed by upland system and the least is lowland system with gross returnofover41% lower than that of irrigated system (Table 4.35).

Table 4.35. Social Prices and budgets for the three Rice Production systems

System	Input/output items	Social Data	
Upland	**Tradable Inputs**	**Prices**	**Budget (₦)**
	d) Fertilizer	923.3 (₦/kg)	83097
	e) Seeds	540 (₦/kg)	14580
	f) Agrochemicals	85 (₦/litr)	5100
	Domestic Inputs		
	v. Total Labour	850 (₦/manday)	29,070
	vi. Depreciation (drum, tarpaulin, bowl, sickles, hoes, cutlass)	780	780
	vii. Bags	1,100	1,100
	viii. Parboiling and Milling	165 (₦/45kg paddy)	7,295.2

	Milled yield (Revenue)	165.8 (₦/kg)	155,041.2
Lowland	**Tradable Inputs**		
	d. Fertilizer	923.3	87713.3
	e. Seeds	540	13500
	f. Agrochemicals	85	6375
	Domestic Inputs		
	5. Total Labour	850 (₦/manday)	30,685
	6. Depreciation (drum, tarpaulin, bowl, sickles, hoes, cutlass)	780	780
	7. Bags	1,100	1,100
	8. Parboiling and Milling	165 (₦/45kg paddy)	7,910.3
	Milled yield (Revenue)	165.8 (₦/kg)	151,144.9
Irrigated	**Tradable Inputs**		
	d) Fertilizer	923.3	92330
	e) Seeds	540	20520
	f) Agrochemicals	85	4675
	Domestic Inputs		
	j. Total Labour	850 (₦/manday)	33,745
	vi. Irrigation/Management	1,695	1,695
	vii. Depreciation (drum, tarpaulin, bowl, sickles, hoes, cutlass)	780	780
	viii. Bags	1,100	1,100
	ix. Parboiling and Milling	165 (₦/45kg paddy)	11,638.4
	Milled yield (Revenue)	165.8 (₦/kg)	257,870.4

4.5.5. Level of profitability and divergences in rice production systems

The values in the columns of private and social budgets in Tables 4.31 and 4.35respectively were used in the PAM analyses and the results of the matrix are shown in Table 4.36. The results revealedthat all therice production systems are privately profitable as shown by positive profits across the three systems. This indicates that the rice production systems were all competitive given the current production technologies, prices of inputs and outputs, and policy and those farmers are earning supernormal return. This result confirms the finding of PCR in Table 4.43 where all systems had value below unity. The implication of this finding is that rice production could be expanded through either rice farmland expansion or substitution of other less competitive crops with rice.

Similar findings were reported by NISER (2010) and Ogbe *et al*. (2011). Also, the results show that social profit for the three rice production systems were all positive, implying that the domestic resources in rice production are been efficiently utilized in the three systems. This evidently reveals that Nigeria has a comparative advantage in the production of rice under the three systems considered. The comparative advantages ranking of the rice systems in descending order is irrigated, upland and lowland systems. This finding confirms the results reported by Ogbe *et al.* (2011) and Liverpool *et al.* (2009).

The third row of PAM contains a measure of the effects of divergence between valuations of products and factors in actual market prices (private or top row of PAM) and in efficiency prices (social or second row of PAM). Divergences are caused either by distorting policies or by market failures. As shown in the Table, there was a positive divergence between private and social profits in all the three rice systems, suggesting that the net effect of policy intervention is to increase profitability of milled rice production in all the ecologies. Thus, the removal of these policy distortions would reduce profitability of milled rice in all the ecologies.

Table 4.36. Policy Analysis Matrices for Three Rice Production Systems (₦/ha)

			Input cost			
System		**Revenue**	**Tradable**	**Domestic**	**Total cost**	**Profit**
Upland	Private	177,670.9	123,630	38,245.2	161,875.2	15,795.7
	Social	155,041.2	102,777	38,245.2	141,022.2	14,019
	Divergences	22,629.7	20,853	0	20,853	1,776.7
Lowland	Private	173,205.9	129,250	40,475.3	169,725.3	3,480.6
	Social	151,144.9	107,588.3	40,475.3	148,063.6	3,081.3

	Divergences	22,061	21,661.7	0	21661.7	399.3
Irrigated	Private	295,508.9	141,720	48,958.4	190,678.4	104,830.5
	Social	257,870.4	117,525	48,958.4	166,483.4	91,387
	Divergences	37,638.5	24,195	0	24,195	13,443.5

4.5.6. Sensitivity analysis on the level of competitiveness

As an analytical methodology, the PAM technique has suffers from the limitation that the analystsare unable to attach any level of confidence to the results and thereforethe findings are consider by some authors (Morrison and Balcombe, 2002; Mohanty *et al*., 2003; Ogbe *et al.*,2011)to be unreliable for effective policy formulation and intervention especially in a dynamic and sensitive production environment. In order to overcome thisdrawback, sensitivity analyses were under taken on some important parameters that affect level of competitiveness of rice production systems.FollowingMohanty *et al*. (2003) and Ogbe *et al.* (2011), the analyses were conducted to test whether the private profit level would be affected or altered by changes in price of fertilizer, farm gate price of outputand increase in yield. In the firstsituation, pricesof fertilizer and milled rice outputwereraised by 10% and also reduced by the same proportion. The results obtained in response to these changes (Tables 4.37, 4.38, 4.39 and 4.40) indicated that these alterations did not have serious effect on the level of competitiveness of rice production especially the upland and irrigated systemsremained competitive in both increase and decrease the price of fertilizerbut the lowland became uncompetitive when the price of fertilizer was increased by 10%.Also, when the price of milled rice output decreased by 10% only irrigated system stayed privately profitable.

Table 4.37.PAM Sensitivity analysis results on the level of competitiveness in rice production systems(price of fertilizer increased by 10%) (₦/ha)

			Input cost			
System		**Revenue**	**Tradable**	**Domestic**	**Total cost**	**Profit**
Upland	Private	177,670.9	133530	38,245.2	171775.2	5895.7
	Social	155,041.2	102,777	38,245.2	141,022.2	14,019
	Divergences	22629.7	30753	0	30753	-8123.3
Lowland	Private	173,205.9	139700	40,475.3	180175.3	-6969.4
	Social	151,144.9	107588.3	40,475.3	148,063.6	3081.3
	Divergences	22,061	32111.7	0	32111.7	-10050.7
Irrigated	Private	295,508.9	152720	48,958.4	201678.4	93830.5
	Social	257,870.4	117,525	48,958.4	166,483.4	91,387
	Divergences	37,638.5	35195	0	35195	2443.5

Table 4.38.PAM Sensitivity analysis results on the level of competitiveness in rice production systems(price of fertilizer decreased by 10%) (₦/ha)

System		Revenue	Input cost			Profit
			Tradable	Domestic	Total cost	
Upland	Private	177,670.9	113730	38,245.2	151975.2	25695.7
	Social	155,041.2	102,777	38,245.2	141,022.2	14,019
	Divergences	22629.7	10953	0	10953	11676.7
Lowland	Private	173,205.9	118800	40,475.3	159275.3	13930.6
	Social	151,144.9	107588.3	40,475.3	148,063.6	3081.3
	Divergences	22,061	11211.7	0	11211.7	10849.3
Irrigated	Private	295,508.9	130720	48,958.4	179678.4	115830.5
	Social	257,870.4	117,525	48,958.4	166,483.4	91,387
	Divergences	37,638.5	13195	0	13195	24443.5

Table 4.39.PAM Sensitivity analysis results on the level of competitiveness in rice production systems(price of milled rice output increased by 10%) (₦/ha)

System		Revenue	Input cost			Profit
			Tradable	Domestic	Total cost	
Upland	Private	195437.99	123,630	38,245.2	161,875.2	33562.79
	Social	155,041.2	102,777	38,245.2	141,022.2	14,019
	Divergences	40396.79	20853	0	20853	19543.79
Lowland	Private	190526.49	129,250	40,475.3	169,725.3	20801.19
	Social	151,144.9	107588.3	40,475.3	148,063.6	3081.3
	Divergences	39381.59	21,661.7	0	21661.7	17719.89
Irrigated	Private	325059.79	141,720	48,958.4	190,678.4	134381.39
	Social	257,870.4	117,525	48,958.4	166,483.4	91,387
	Divergences	67189.39	24,195	0	24,195	42994.39

Table 4.40.PAM Sensitivity analysis results on the level of competitiveness in rice production systems(price of milled rice output decreased by 10%) (₦/ha)

System		Revenue	Input cost			Profit
			Tradable	Domestic	Total cost	
Upland	Private	159903.81	123,630	38,245.2	161,875.2	-1971.39
	Social	155,041.2	102,777	38,245.2	141,022.2	14,019
	Divergences	4862.61	20853	0	20853	-15990.39
Lowland	Private	155885.31	129,250	40,475.3	169,725.3	-13839.99
	Social	151,144.9	107588.3	40,475.3	148,063.6	3081.3
	Divergences	4740.41	21,661.7	0	21661.7	-16921.3
Irrigated	Private	265958.01	141,720	48,958.4	190,678.4	75279.6
	Social	257,870.4	117,525	48,958.4	166,483.4	91,387
	Divergences	8087.61	24,195	0	24,195	-16107.4

In the second scenario, similar analysis wascarried out to test the possible impact of the changes in the quantity of milled rice output on the level of competitiveness of rice

production in the three systems. The quantity of milled rice output was increased and decreased by 10%. The result obtained (Tables 4.41 and 4.42) when the quantity of milled output were increased by 10% did not affect or alter level of private profitability of the rice production irrespective of the system. However, only irrigated system remained privately profitable when the quantity milled output was decreased by 10%.

Table 4.41.PAM Sensitivity analysis results on the level of competitiveness in rice production systems(Milled yieldincreased by 10%) (₦/ha)

			Input cost			
System		**Revenue**	**Tradable**	**Domestic**	**Total cost**	**Profit**
Upland	Private	195437.99	123,630	38,245.2	161,875.2	33562.79
	Social	155,041.2	102,777	38,245.2	141,022.2	14,019
	Divergences	40396.79	20853	0	20853	19543.79
Lowland	Private	190526.49	129,250	40,475.3	169,725.3	20801.19
	Social	151,144.9	107588.3	40,475.3	148,063.6	3081.3
	Divergences	39381.59	21,661.7	0	21661.7	17719.89
Irrigated	Private	325059.79	141,720	48,958.4	190,678.4	134381.39
	Social	257,870.4	117,525	48,958.4	166,483.4	91,387
	Divergences	67189.3	24,195	0	24,195	42994.39

Table 4.42.PAM Sensitivity analysis results on the level of competitiveness in rice production systems(Milled yielddecreased by 10%) (₦/ha)

			Input cost			
System		**Revenue**	**Tradable**	**Domestic**	**Total cost**	**Profit**
Upland	Private	159903.81	123,630	38,245.2	161,875.2	-1971.39
	Social	155,041.2	102,777	38,245.2	141,022.2	14,019
	Divergences	4862.61	20853	0	20853	-15990.39
Lowland	Private	155885.31	129,250	40,475.3	169,725.3	-13839.99
	Social	151,144.9	107588.3	40,475.3	148,063.6	3081.3
	Divergences	4740.41	21,661.7	0	21661.7	-16921.29
Irrigated	Private	265958.01	141,720	48,958.4	190,678.4	75279.61
	Social	257,870.4	117,525	48,958.4	166,483.4	91,387
	Divergences	8087.61	24,195	0	24,195	-16107.39

4.5.7 Test of hypothesis

The PAM methodwas used to test the hypothesis4and the results are shown in Table 4.43. From the table, the DRC coefficients for all production systems were positive and below unity in value, indicating that the values of domestic resources used in rice production in

the three systems are lower than the value added. This implies an efficient utilisation of domestic resources in rice production and that production in all the systems were socially profitable and this validates and confirms the comparative advantage result in Table 4.36. Accordingly, study areas have a comparative advantage in rice production. This leads to the rejection of the null hypothesis that states the study areas have no comparative advantage in rice production. The irrigated and upland systems were relatively more profitable in terms of use of domestic factors owing to their lower DRC value of 0.32 and 0.71 respectively.

The degree of protection givento the value added process is indicated by the effective protection coefficient (EPC). From the table, EPC had a positive and values greater than unity for the rice systems with the exception of lowland system which had a value of 0.10. This denotes that rice farmersunder upland and irrigated systems wereprotected through policy intervention on value added processes but thosefarmers under lowland systemare not protected through government support and thereforeface net tax of 10%. This may probably be attributed to the problem of empty panicle recorded in the lowland system resulting from low amount of water at critical productive stage and blast infestation, which there was no recorded response from the government on the problems at the time of the survey.

Also, the results show that the NPCO coefficient values are positive and greater than unity in all the three systems of rice production, indicating that domestic farm gate price

is greater than the international price for rice output and through government policies like increased import tariff or ban on rice importation the market prices are increased to a level of 15% above the international price as shown by results in all the systems. This suggests that productions in the three systems are protected by policy.This may be associated with the import tariff on riceand subsidizedinputs like fertilizer, agrochemicals and improved seeds through the Growth Enhancement Scheme (GES) programme. The GES programme is trying to assured the farmers on the inputs timely availability and quality as well as lower prices compared to the open markets prices,even though most of the farmers were not adequately assessing these inputs in the study areas.

Table 4.43. Summary of policy indicators for the three rice production systems.

	Rice production systems		
Indicator	**Upland**	**Lowland**	**Irrigated**
Private cost ratio	0.71	0.92	0.32
Domestic resource cost ratio	0.73	0.93	0.35
Effective Protection Coefficient	1.03	0.10	1.10
Nominal Protection Coefficient on Output	1.15	1.15	1.15

4.6 Problems of Rice production in the Study Area

Rice production in the study areas is not only very important in the country's food security but also in rural employment, poverty reduction, biodiversity, and cultural and tradition conservation. It has been observed that rice production process in the three main rice production systems is constrained by many bio-physical and economic factors.The major constraints that hindered rice farmers from achieving their full production potentialsare presented in Table 4.44. Low output prices, high cost of inputs, pests and diseases, inadequate credit facilities and marketing problemswere the most prominent problems militating against rice production in the study areas.

Low output price is ranked first in all the three rice production systems as the highest proportion of the farmers in upland (30.9%), lowland (33.3%) and irrigated (18.4%) systemsreported low output prices as their major problem limiting rice production. This may be connected with the sale of output immediately after harvest at farm gate price in order to meet up with pressing financial needs of the family. It is a general believed that at the time of harvest, agricultural outputs are cheaper and their values appreciate as time goes on. This finding confirms that of Ayinde *et al.* (2014) which observed that the main constraint face by rice farmers in Nigeria was low output prices.Few farmers from upland system (5.5%) and irrigated system (7%) pointed out that they sold their output at farm gate prices immediately after harvest because of storage facilities problem.

The high cost of production inputs was reported as the second most pressing problem militating against rice production in upland (19.1%) and third major problem in irrigated (14.5%) and lowland (15.1%) systems. At the time of the survey, rice production inputs such as fertilizer, improved seeds andagrochemicals were observed to be very expensive in the study areasand the subsidized inputs under GES is not reaching the actual rice farmers as complained by the farmers. This finding confirms the results of Ojehomon *et al.* (2009) and Abdullahi (2014).

Inadequate credit facilities, pests and diseasesand transportation problems were among the major problems associated with rice production in the study areas.Poorly organized

and uncoordinated markets for rice output and the activities of middlemen usually increase the widening gap of price margin received by the farmers.All theseproblems were significantly reported in all the three rice production systems.

Table 4.44 Problems Faced by Rice Farmers in the Study Area

Major Constraints	**Rice production systems**					
	Upland		**Lowland**		**Irrigation**	
	Frq	**%**	**Frq**	**%**	**Frq**	**%**
Low output prices	34	30.9	42	33.3	29	18.4
High cost of inputs	21	19.1	19	15.1	23	14.5
Pestsand diseases	8	7.3	7	5.6	19	12.0
Inadequate credit facilities	19	17.2	17	13.4	8	5.1
Marketing problems	12	10.9	20	15.9	27	17.1
Storage problems	6	5.5	8	6.4	11	7.0
Transportation Problems	10	9.1	13	10.3	8	5.1
Labour shortage	-	-	-	-	14	8.8
Irrigation water shortage	-	-	-	-	19	12.0
Total	**110***	**100**	**126***	**100**	**158***	**100**

**Note: ***Multiple responses allowed.Frq stands for Frequency

The implication of the finding as expressed in Table 4.44above is that rice farmers in the study areas are constrained bio-physically and socio-economically. And for them to operate at their frontiersto produce enough to meet up the domestic demand and even export surplus, these highlighted problems should be addressed squarely. By addressing these problems the production capacity of the farmers and competitiveness will be enhanced andthereby substitutingimport ricefully.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMMENDATIONS

5.1 Summary

There is deficit in domestic demand and supply of rice in Nigeria. The shortfall of about 3MT is bridged through importation. Nigeria, the largest importer of rice in Africa and second in the World, is blessed with huge and abundant natural resources suitable for producing more than enough rice to meet up the domestic demand and even to export the

surplus.Many Government policies targeted to increase rice production are not yielding positive results and the demand-supply gap is continuously widening.

Basically, there are three ways to increase rice production in Nigeria i) by increasing cropped land area under rice production b) by adopting new technology and c) by using available resources efficiently. The third option is the most suitable because this option does not require more areas and development of new technology. Broadly, the present study was designed to analyse production efficiency and competitiveness of rice production systems in three selected states of Northern Nigeria. The specific objectives were to: describe the socioeconomic characteristics of rice farmers in the study area, estimate the farm-level technical, allocative, economic and scale efficiencies in rice production, ascertain the sources of technical and allocative inefficiencies differentials among rice farmers, determine the technology gap ratios among the major rice producing systems, determine the level of competitiveness of rice production in the three major rice systems, and describe the constraints to rice production in the study area. The hypotheses tested in the study were: rice farmers are not operating on the technical efficient frontier, socioeconomic characteristics of rice farmers have no effect on the technical efficiency, the stochastic production frontiers for all the rice production systems are the same and the study areas have no comparative advantage in rice production.

To achieve the stated objectives of the study and test the hypotheses, both primary and secondary data were collected. The primary data were collected from rice farmers in the three major rice producing systems with aid of pretested questionnaire.The sampling technique used for primary data collection wasmulti-stage sampling techniquewhere 278 rice farmers were selected for the study. The primary data collected were analysed using descriptive statistics, stochastic frontier functions,stochastic metafrontier model, and PAM approach.The secondary data on transportation costs, port charges, storage costs, production subsidy, import tariffs, and exchange rate were obtained from the relevant agencies and publications.

The results indicated that over 88% of the farmers were between the active ages of 26 and 55 years. Only 8% of the respondents had no formal education. Land acquisition was mainly (68%) through inheritance while the average farm size was 2.7 hectares. Furthermore, the findings revealed that the mean years of rice production experience was 17 years while the majority (84.9%) of the farmersis male and about 86% of the farmers belong to farmers' organization. It was found from the study that there is no significant mean difference among most of the socio-economic characteristics of the three major rice producing systems.

The stochastic frontier functions were estimated under the specification of the translog production and cost function models for the three systems. The mean technical efficiency scores were 0.642 for upland, 0.622 for lowland and 0.734 for irrigated system while the mean allocative efficiency scores were 0.462 for upland, 0.381 for lowland and 0.514 for irrigated system. This suggests that the mean economic efficiency for the three rice

production systems were all below unity, indicating that all the systems are economicallyinefficient because of technical and allocative inefficiencies. Hence, the simultaneous improvements of both technical and allocative efficiencies are necessary for the effective achievement of economic efficiency among rice farmers in all the three rice production systems.

An attempt was made to ascertain the determinants of technical and allocative efficienciesof rice farms. Some socio-economic characteristics of farmers were included in the inefficiency effects models. The years of rice production experience, years of schooling, number of extension visits on rice production practices in the surveyed season, years spent as member in farmers' cooperative,and farm size were significant factors found to reduce bothtechnical and allocative inefficiencies in rice production in the study areas.The percentage yield loss due to technical inefficiency for upland, lowland and irrigated systems were about 56%, 61% and 36% in that order.The most common type of scale inefficiency among the rice production systems is IRS. The average scale efficiency score was higher for lowland system (0.81) followed by upland (0.80) and the least was irrigated (0.72) system.The existence of heterogeneous technologies in rice production rationalises the utilisation of the metafrontier, under which the relevant technical efficiencies are evaluated against the common stochastic production frontier. The mean values for the TGR for upland, lowland and irrigated systems were 0.446, 0.377 and 0.538 respectively.The maximum TGR value of unity for the irrigated system indicates that the system stochastic frontier is tangent to the metafrontier.

The level of competitiveness and comparative advantage and degree of protection of rice production systems were computed using the PAM framework. The results revealed that

all therice production systems were both privately and socially profitable and this indicates that the rice production systems were all competitive and have comparative advantage. Similarly, the rice production systems (upland and irrigated) received protection from Government intervention as indicated by values of EPC which were positive and greater than unity but lowland farmers were not protected. Also, all the three rice production systems receive from protection through government policies as shown by the values of NPCO greater than unity.

The major constraints that hindered rice farmers from achieving their full production potentials were low output prices, high cost of inputs, pests and diseases, inadequate credit facilities and marketing problems.

5.2 Conclusions

Based on the findings of this study, it is concluded that the rice farmers in the major rice producing systems were technically, allocatively, economically and scale inefficient. The significant factors that increasedrice farmers' technical and allocative efficiencies in the three systems of production werethe years of rice production experience, years of schooling, number of extension visits, years spent as member in farmers' cooperative,and farm size.The wide gap between the metafrontier and the relative frontiers of the three systemsis due to inefficiency in rice production and this gap can be reduced by adopting superior rice production techniques and enhancing efficiencies of farmers. All the rice production systems were both privately and socially profitable.Low output prices, high cost of inputs, pests and diseases, inadequate credit facilities and marketing problems were the main constraints facing rice farmers in the three rice production systems.

5.3Recommendations

In order to sustain and improve efficiency and competitiveness of rice production systems in the study areas, the following suggestions and policy recommendations are drawn from the study's results:

i) An analysis of the factors affecting efficiency indicated which aspects of the farms' human and physical resources might be targeted by public investment to improve farm efficiency. Farming experience and years of schooling are

both significant variables for improving efficiency. Policies designed to formally educate farmers especially the more experience rice farmers could have a great impact in increasing the level of efficiency and productivity.

ii) Extension contact is a significant variable for improving both technical and allocative efficiency; therefore, policies formulated to educate people through proper agricultural extension services could have positive impacts on the levels of efficiency and agricultural productivity.

iii) Farmers should be encouraged to form farmers' cooperative or group through which government and relevant agencies could find ease in reaching large number of rice farmers at a time and at a cost. Other benefits of grouping can be reaped by the farmers like group lending and group marketing.

iv) Since increase in farm size reduces both technical and allocative inefficiencies and the most common type of scale inefficiency among the rice production systems is increasing return to scale (IRS), a policy to prevent land fragmentation into smaller uneconomic sizes should be enforced. There is need to promote consolidation of farm lands into large commercial sizes as this will encourage mechanisation and afford the farmers opportunity for access to credit facilities.

v) There are many farms operating off the metafrontier and these farms need to catch up with the potential technology defined by the metafrontier in order to be competitively viable. This can be achieved through adoption of superior

technologies. Therefore, strategies to improve accessibility of improved technologies by rice farmers and to increase adoption rate should be designed.

vi) For the domestic rice to properly compete with the imported rice, farmers should device means of making their rice look more attractive to consumers for more patronage and fetch higher price. This can be achieved through adopting modern production inputs and post-harvest packaging.

vii) Farm inputs such as fertilizer and improved seedsare found to have significant impacts on total paddy production and therefore policy to enhance their availability, affordability and quality standard should be formulated by relevant agencies.

viii) Government should continue to protect domestic rice industry by strictly enforcing and increasing import tariff on rice import and as well as reducing the production cost in domestic rice production.

ix) Government should reallocate more rice production resources to irrigated system in the country since rice production under irrigated system is more profitable both privately and socially. This will surely hastens the realisation of self-sufficiency in rice production. The expansion and rehabilitation of existing irrigation sectors in the country would contribute immensely to achievement of rice self-sufficiency goal.

5.4Contributions to Knowledge

Holistically, the Nigerian rice production systems especially the three major rice producing systems in the country have been extensively studied both at the micro and macro-economic levels (rice farmers' efficiencies and ecological and international

competitiveness). Consequently, current and updated information have been contributed into the body of knowledge which includes the following:

1. Information regarding factors that influence rice farmers' efficiency in the major rice producing ecologies in Nigeria will be of great interest to policy makers in the country that are currently dealing with ways to attain food security through self-sufficiency in rice production. The study has contributed to identifying those factors that affect rice farmers' technical and allocative efficiencies for proper efficiencies enhancing policy formulation. These factors include years of rice production experience, which is significantly reduce technical inefficiency at 10% levelin all the production systems and enhance allocative efficiency at 1% in lowland and irrigated systems and 5% in upland. Years of schooling increase technical efficiency at 1%, 10% and 5% in upland, lowland and irrigated systems respectively and found to reduce allocative inefficiency at 5% in upland and 1% in lowland and irrigated systems. Other factors that significantly reduce inefficiencies in rice production include number of extension visits on rice production practices, years spent as member in farmers' cooperative and farm size.
2. Relatively, irrigated system of rice production is more efficient both technically (73.4%) and allocatively (51.4%) and in the overall economic efficiency (38.2%). Therefore, more resources can be deployed into rice production under irrigated system for efficient allocation of scarce productive resources.
3. The study contributed that there are many rice farms especially under lowland and upland systems of production that are operating off the metafrontier and these

farms need to catch up with the potential technology defined by the metafrontier in order to be competitively and efficiently viable. The mean values for the TGR for upland, lowland and irrigated systems were 0.446, 0.377 and 0.538 respectively.

4. It has been revealed that Nigeria has comparative advantage in rice production. Irrigated system of rice production is more efficient both privately (₦104,830.5) and socially (₦91,387), followed by upland system with private profit of₦15,795.7 andwith social profit of ₦14,019. The least efficient is lowland system with private profit and social profit of ₦3,480.6 and₦3,081.3 respectively.
5. Very effective, stable, reliable and consistent conversion factors were evolved from the study. The conversion factor for upland, lowland and irrigated paddy output into milled rice output equivalent were 0.47 0.42 and 0.49 respectively.
6. Among the rice production problems, low output prices is ranked first in all the production systems, high cost of inputs is ranked second in upland and irrigated systems while marketing problems is ranked second in lowland.Pests and diseases, inadequate credit facilities and marketing problems were also among the main constraints facing rice farmers in the three rice production systems.
7. Practical guides for the estimation of Metafrontier techniques for those who want to apply the methodology is elaborated and the code is appended as Appendix 9.

5.5 Limitations of the Study

The survey experienced several problems which are common to many fieldwork experiences. The most serious problems were:-

i) Lack of records keeping by the farmers – The habit of farm records keeping is not practiced by the farmers, even though only few (5%) had no formal education (Table 4.3). All the farmers interviewed provide the needed information from memory.

ii) Financial constraints on the side of the Researcher – This has limited the researcher to only cover three rice production systems out of the five prominent systems of rice production in Nigeria and only 7% (278)rice farmers out of the sample frame of the rice farmers were used in the study. The researcher is fully aware that the larger the sample size, the more the representativeness of the population and the more accurate the parameters of the population will be estimated.

iii) Cross sectional data for a single production season – A panel data for wide range of production seasons will be needed to evaluate how efficiency has changed over time in the study area. The collected data was not suitable for such technical efficiency's trend evaluation.

5.6 Suggestions for Further Research

The scope of this study can be enlarged in different directions, one of which could be to apply alternative functional Cobb-Douglas production function and constant elasticity of substitution (CES) production functions to the larger data. Also a cost route approach to data collection can be adapted to accurately collect reliable data and to deliberately avoid sampling error. Moreover, the utilisation of a computable general equilibrium (CGE) model to assess the policy impact of the rice sector in Nigeria could be considered.

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Appendix 1:Farmers' Questionnaire

IDENTIFICATION OF THE INTERVIEW

State……. LGA……. Village ……..……..……
Rice Ecology……..… Questionnaire No.…… Date ……. Name of Interviewer …… GSM No:…..……..**.....**……..……

SECTION A. BACKGROUND INFORMATION OF RICE FARMER.

1. Name of farmer …… (Optional) 2. Sex: i) Male ( ) ii) Female ( )
3. Age ……..….. years 4. Marital status: a) Married ( ) b) Single ( ) c). Widow ( ) d) Divorced ( ) 5. Total Household size …..……. persons:
a) Number of wives …….. b) Number of male children (1 – 18 years) ……..
c) Number of female (1 – 18years)…….. d) Number of adult (both male and female) (above 18years) ……..…….
6. Educational qualification:
a) Non formal education ( ) b) Quranic education ( ) c) Adult education () (d) Primary education ( ) e) Secondary education ( ) f) Tertiary/University education ( )
7. Give total years of formal schooling ……..… years
8. Do you belong to any farmers' cooperatives/associations? Yes ……. No ……
9. Give three major activities of the cooperative/association:
i…….
ii. ……..……
iii. ……..……
10. Give the number of years spent as a member in the cooperative….……..… years
11. Do you have access to extension visits? Yes ……...No …….
12. If yes in 11 above, give approximate number of visits received or paid to sources of extension services in this production season ……
13. Where is the extension agent coming from? ……
14. Is farming your major occupation? i. Yes ( ) ii. No ( ).
15. If no to 11 above, what others things do you do?
a) Trading ( ) b) Fishing ( ) c) Tailoring ( ) d) Civil Servant ( ) e) Others (specify) ….....
16. Give an approximate annual income from other off farm activities ₦…….....

SECTION B FARMING ACTIVITIES

17. Number of years spent in general farming …….....years

18. Number of years spent in rice production …… years
19. What is your major source for information on improved rice production practices?
a) Extension agents/materials ( ) b) Radio/Television ( ) c) Market place ( ) d) other farmers e) farmers' cooperative/association ( ) f) other (specify) ……....
20. Do you use improved seeds? i. Yes ( ) ii. No ( )
21. If yes, what are the major sources? i……..….. ii……..… iii……..…
22. What is your approximate distance to seeds markets? ……. km
23. Do you have access to credit? Yes ( ) No ( )
24. What are the sources of the credit? a) Commercial banks ( ) b) Money lenders ( ) c) cooperatives ( ) d) Friends/family ( ) e) Rural buyers ( ) f) NGOs ( ) g) Government ( )
25. If yes to 23 above, how much did you use in the last rice production season? ₦……
26. How many plots of rice cultivation do you have? ……..
27) How did you acquire your farmland(s)? i. Through inheritance ( ) ii. Purchase ( ) iii. Rent ( ) iv. Gift ( ) v. other (specify) ……
28) If the land was rented, how much did you pay per annum? ₦/ha ……..……
28) If the land was purchased, what was the amount paid ₦/ha ……
29) What is the total size of land put to rice production? …….. ha
30) What was the mode of cultivation on the rice field? i. animal traction ( ) ii. tractor hiring ( ) iii. Hand implements ( ) iv. Others (specify) ……
31. If irrigated ecology, please answer the following questions:
a. What is/are source(s) of irrigation water? i. ……. ii……
b. Mode of irrigation i. Mechanized ( ) ii. Manual ( ) iii.
c. Approximate cost of irrigating the total rice land in a season ₦ ……
32) If you employ the service of a tractor, Please fill the table below.
Plot No ……

Farm operation	**Size of land (ha)**	**Time (hour)**	**Amount paid (₦)**

Plot No …….

Farm operation	**Size of land (ha)**	**Time (hour spent)**	**Amount paid (₦)**

33) State the labour contribution of your family members and hired labour during the last cropping season.

A) Family labour:

FARM OPERATIONS	**No OF WORKERS BY TYPE OF LABOUR**			**ACTUAL HOURS SPENT**			**No OF DAYS WORK**		
	MA	**FA**	**LC**	**MA**	**FA**	**LC**	**MA**	**FA**	**LC**
Land clearing									
Ridging/ Ploughing									
Planting									
Fertilizer Application									
Weeding 1st wedding 2nd wedding									
Spraying									
Harvesting									
Irrigation									
Transportation									
Others (Specify)									

MA = Male adult, FA= Female adult, LC= Large children (8 – 15years)

B) Hired labour

FARM OPERATION	**No OF WORKERS BY TYPE OF LABOUR**			**ACTUAL HOURS SPENT**			**No OF DAYS WORK**		
	MA	**FA**	**LC**	**MA**	**FA**	**LC**	**MA**	**FA**	**LC**
Land clearing									
Ridging/ Ploughing									
Planting									
Fertilizer Application									
Weeding 1st wedding 2nd wedding									
Spraying									

Harvesting									
Irrigation									
Transportation									
Others (specify)									

34) FARM INPUT RECORD

Plot No: …….

Inputs	**Quantity**	**Unit Price(₦)**	**Total(₦)**
Recycled Seeds(kg)			
Improved Seeds (kg)			
fertilizers(kg)			
Agrochemicals(litres)			
farm implements			
manure(kg)			
Irrigation			
others (specify)			

Plot No: …….

Inputs	**Quantity**	**Unit Price(₦)**	**Total(₦)**
Recycled Seeds(kg)			
Improved Seeds (kg)			
fertilizers(kg)			
Agrochemicals(litres)			
farm implements			
.manure(kg)			
Irrigation			
others (specify)			

35) CROP OUTPUT DATA

Plot No: ……

Crop	**No of bags**	**Kg/bag**	**Price / bag**	**Total (₦)**
rice				
stalk				
Other by-products				
Quantity consumed				
Quantity give out as gift				

Plot No: ……

Crop	**No of bags**	**Kg/bag**	**Price / bag**	**Total (₦)**
rice				
stalk				

Other by-products				
Quantity consumed				
Quantity give out as gift				

36) Did you encounter any problems in rice production last cropping season?
Yes ( ) No ( )
37) If yes, what were the natures of the problems? ……....
……
38) Please rank the problems in order of importance to your rice farms:
i. …… ii…….. iii……..
iv…… v…….vi…….
39) What can you suggest for improvement with regards to the problems mentioned above? ……
……

SECTION C: MARKETING INFORMATION

40) Where do you sell your rice?
i) On the farm ( ) ii) Assemblers iii) Village market ( ) iv) Urban market ( )
v) Others (specify) ……...
41) When do you sell your rice? i) Immediately after harvest ( ) ii) 1 week after harvest ( ) iii) others (specify)……..…
42) Why do you sell your output in the specified period in question (40) above?……..
43) Did you encounter any problems in rice marketing last season?
Yes ( ) No ( )
44) If yes, what were the natures of the problems? ……..……
……
……
45) Please rank the problems in order of importance to your rice farmers:
i. …… ii…….. iii…….
iv…… v…….vi……
46) What can you suggest for improvement with regards to the problems mentioned above? ……..
……..

Thanks for your time

Appendix 2: Upland System Stochastic Frontier Production Results

the final mle estimates are :

Variables	coefficient	standard-error	t-ratio
Constant	0.34618469E+01	0.77036957E+00	0.44937482E+01
lnseed	0.22312200E+00	0.98698048E-01	0.22606526E+01
lnlabour	0.52801431E-01	0.19178462E-01	0.27531630E+01
lnfertilizer	0.10042278E+00	0.47212540E-01	0.21270360E+01
lnirrg	0.56412035E+00	0.40181738E+01	0.14039222E+00
lnseed sqr	0.25642580E+00	0.28450057E+00	0.90131919E+00
lnlabour sqr	0.84759368E+00	0.40208190E+00	0.21080123E+01
lnfertilizer sqr	0.41561690E-01	0.79734476E-01	0.52125118E+00
lnirrg sqr	0.21113533E+00	0.21037858E+00	0.10035971E+01
lnseed*lnlabour	0.16091266E-01	0.69959671E-02	0.23000776E+01
lnseed*lnfertilizer	0.42634925E+00	0.21457685E+00	0.19869303E+01
lnseed*lnirrg	0.76105129E+00	0.60322381E+00	0.12616400E+01
lnlabour*lnfertilizer	0.10450838E+01	0.56126838E+00	0.18620037E+01
lnlabour*lnirrg	0.31990507E+00	0.55911949E+00	0.57215868E+00
lnfertilizer*lnirrg	0.95144952E+00	0.82193010E+00	0.11575796E+01
Constant	0.45209397E+00	0.39950858E+00	0.11316252E+01
Age	0.53761097E-01	0.14257208E-01	0.37708013E+01
Years of farming exp	-0.38208819E-01	0.20647785E-01	-0.18505045E+01
Years of schooling	-0.55117991E-01	0.16687692E-01	-0.33029128E+01
Household size	0.35832979E-01	0.25230516E-01	0.14202238E+01
Distance to market	0.77620636E-02	0.33090048E-01	0.23457396E+00
Extension visit	-0.18944694E-01	0.33261342E-02	-0.56957094E+01
Years in cooperative	-0.82123034E-02	0.11826623E-02	-0.69439157E+01
Amount of credit	-0.37132807E-02	0.14140884E-02	-0.26259183E+01
Farm size	-0.10154884E-01	0.43082644E-02	-0.23570712E+01
Tenancy	0.34876954E+00	0.20560474E+00	0.16963108E+01
sigma-squared	0.40984585E-01	0.14421321E-01	0.28419438E+01
gamma	0.70594813E+00	0.14052795E+00	0.50235425E+01

log likelihood function = 0.54225022E+02

LR test of the one-sided error = 0.39710504E+02

Appendix 3: Lowland System Stochastic Frontier Production Results

the final mle estimates are :

Variable	coefficient	standard-error	t-ratio
Constant	0.89332928E+01	0.90225353E+00	0.99010894E+01
lnseed	0.90376414E+00	0.42308629E+00	0.21361260E+01
lnlabour	0.14133778E-01	0.64221114E-02	0.22006860E+01
lnfertilizer	0.13376614E-01	0.65811046E-02	0.20327451E+01
lnirrg	0.26196124E+00	0.19919434E+00	0.13151077E+01
lnseed sqr	0.30796182E+00	0.21699890E+00	0.14191861E+01
lnlabour sqr	0.18902851E+00	0.10023659E+00	0.18858234E+01
lnfertilizer sqr	0.11242373E+00	0.66465196E-01	0.16914744E+01
lnirrg sqr	0.16142328E-01	0.15490688E-01	0.10420666E+01
lnseed*lnlabour	0.15516246E-01	0.15443433E+00	0.10047148E+00
lnseed*lnfertilizer	0.42453520E-02	0.24708547E-02	0.17181832E+01
lnseed*lnirrg	0.67572648E-01	0.57610255E-01	0.11729274E+01
lnlabour*lnfertilizer	0.28978969E+00	0.12970437E+00	0.22342323E+01
lnlabour*lnirrg	0.36146778E-01	0.43302423E-01	0.83475186E+00
lnfertilizer*lnirrg	0.80193140E-01	0.48552443E-01	0.16517686E+01
Constant	0.63533294E+00	0.77506369E+00	0.81971708E+00
Age	0.38134762E-01	0.15562978E-01	0.24503512E+01
Years of farming exp	-0.76217362E-02	0.40323513E-02	-0.18905415E+01
Years of schooling	-0.24352858E-01	0.13868395E-01	-0.17560838E+01
Household size	0.12089774E+00	0.76898438E-01	0.15721869E+01
Distance to market	0.37543879E-01	0.97239444E-01	0.38609722E+00
Extension visit	-0.11074886E+00	0.51070474E-01	-0.21685870E+01
Years in cooperative	-0.24916984E-01	0.11810426E-01	-0.21098668E+01
Amount of credit	-0.53155392E-05	0.26392842E+00	-0.20140087E+01
Farm size	-0.22519798E-01	0.12161012E-01	-0.18517986E+01
Tenancy	0.16399229E+00	0.22953569E+00	0.71445227E+00
sigma-squared	0.29990417E+00	0.41913263E-01	0.71553524E+01
gamma	0.74475760E+00	0.34343222E+00	0.21685753E+01

log likelihood function = 0.46667185E+02

LR test of the one-sided error = 0.71083240E+01

Appendix 4: Irrigated System Stochastic Frontier Production Results

the final mle estimates are :

Variablecoefficient	standard-error	t-ratio
Constant0.87327861E+01	0.13304513E+01	0.65637775E+01
lnseed0.65995289E+00	0.30259087E+00	0.19832763E+01
lnlabour0.41062345E+00	0.22597979E-01	0.47010953E+01
lnfertilizer	0.74469828E-01	0.30019436E-01	0.24807884E+01
lnirrg 0.73661796E+00	0.20539819E+00	0.35863010E+01
lnseed sqr0.34895828E+00	0.17619610E+00	0.19805174E+01
lnlabour sqr0.90514743E+00	0.68018377E+00	0.13307395E+01
lnfertilizer sqr	0.41174638E-01	0.51592171E+01	0.79807922E-02
lnirrg sqr0.55648432E-01	0.19396212E-01	0.28690881E+01
lnseed*lnlabour0.13099094E+01	0.39897647E+00	0.32831746E+01
lnseed*lnfertilizer0.74132403E-01	0.36537401E-01	0.20289565E+01
lnseed*lnirrg	0.67715529E+00	0.39895919E+00	0.16973050E+01
lnlabour*lnfertilizer	0.21770999E+00	0.11298337E+00	0.19269238E+00
lnlabour*lnirrg 0.91230524E+00	0.12547778E+00	0.72706515E+01
lnfertilizer*lnirrg	0.32062733E+00	0.11741649E+00	0.27306691E+01
Constant0.49009311E+00	0.70048494E+00	0.69964832E+00
Age0.75731884E-02	0.32671152E-02	0.23177854E+01
Years of farming exp	-0.87191051E-02	0.49110414E-02 -0.17753544E+01
Years of schooling-0.16960123E-01	0.76680497E-02 -0.22116624E+01
Household size0.14659847E-01	0.36290887E-01	0.40395416E+00
Distance to market0.34597081E-01	0.12641024E+00 0.27368890E+00
Extension visit-0.24337848E-01	0.86338910E-02 -0.28192104E+01
Years in cooperative -0.10008944E-01	0.39319186E-02 -0.25465344E+01
Amount of credit-0.91475025E-02	0.50330217E-02 -0.18176218E+01
Farm size-0.18639093E-01	0.65731812E-02 -0.28356041E+01
Tenancy0.82522367E-01	0.11272717E+00 0.73205394E+00
sigma-squared 0.71134699E-01	0.23919002E-01	0.29739514E+01
gamma0.62599999E+00	0.16261105E+00	0.38496705E+01

log likelihood function = 0.61351590E+02

LR test of the one-sided error = 0.38864048E+02

Appendix5: Stochastic Frontier Production Results for Pooled Samples

the final mle estimates are :

Variable	coefficient	standard-error	t-ratio
Constant	0.97486581E+01	0.31342577E+01	0.31103560E+01
lnseed	0.10314521E+00	0.21158021E-01	0.48750581E+01
lnlabour	0.77423717E+00	0.41789080E+00	0.18526840E+01
lnfertilizer	0.27343100E+00	0.96348087E-01	0.28379691E+01
lnirrg	0.80594300E+00	0.57146483E+00	0.14103120E+01
lnseed sqr	0.46242763E+00	0.20970319E+00	0.22051533E+01
lnlabour sqr	0.68476508E+00	0.53533928E+00	0.12791240E+01
lnfertilizer sqr	0.44253409E+00	0.19237427E+00	0.23003761E+01
lnirrg sqr	0.14875505E+00	0.17202580E+00	0.86473272E+00
lnseed*lnlabour	0.21505611E+00	0.98928351E-01	0.21938171E+01
lnseed*lnfertilizer	0.55826920E+00	0.28031763E+00	0.19915613E+01
lnseed*lnirrg	0.27783520E+00	0.33630593E+00	0.82767800E+00
lnlabour*lnfertilizer	0.57250220E-02	0.33281159E-02	0.17203752E+01
lnlabour*lnirrg	0.40992080E-01	0.28120761E-01	0.14577743E+01
lnfertilizer*lnirrg	0.10967054E+00	0.60297194E-01	0.18188562E+01
Constant	0.32871068E+01	0.31273227E+01	0.10510929E+01
Age	0.79537640E-02	0.41012938E-02	0.19393551E+01
Years of farming exp	-0.22187604E-01	0.79079850E-02	-0.28057215E+01
Years of schooling	-0.10656502E-01	0.46857833E-01	-0.22740211E+00
Household size	0.19807963E-01	0.14781786E-01	0.13399734E+01
Distance to market	0.18893242E+00	0.14670828E-03	0.12878064E+01
Extension visit	-0.12430694E-02	0.55089289E-03	-0.22565229E+01
Years in cooperative	-0.57181766E-02	0.22388451E-02	-0.25539883E+00
Amount of credit	-0.13711520E-04	0.43356563E-05	-0.31625016E+01
Farm size	-0.13727957E-02	0.63715033E-03	-0.21555761E+01
Tenancy	0.12534063E+00	0.10303176E+00	0.12165242E+01
sigma-squared	0.59774549E+00	0.50721204E-01	0.11790141E+02
gamma	0.67563240E+00	0.19631119E+00	0.34418960E+01

log likelihood function = 0.32169293E+03

LR test of the one-sided error = 0.53958884E+02

Appendix 6: Upland System Stochastic Frontier Cost Function Results

the final mle estimates are :

Variable	coefficient	standard-error	t-ratio
Constant	0.34484520E+01	0.40004522E+00	0.86114066E+01
lnseed	0.31427273E+00	0.15744253E+00	0.19961187E+01
lnlabour	0.78846432E-01	0.25233382E-01	0.31247454E+01
lnfertilizer	0.47432020E-01	0.15407919E-01	0.30784440E+01
lnirrg	0.97578104E+00	0.85416619E+00	0.11423780E+01
lnseed sqr	0.18926085E+00	0.72959034E+01	0.25940700E+01
lnlabour sqr	0.24114403E+00	0.11198843E+00	0.21535604E+01
lnfertilizer sqr	0.16008530E+00	0.66223385E-01	0.24173327E+01
lnirrg sqr	0.15475113E+00	0.55567888E+00	0.27849032E+00
lnseed*lnlabour	0.41668526E+00	0.47730605E-01	0.87299386E+01
lnseed*lnfertilizer	0.27774863E-01	0.22650329E-01	0.12262455E+01
lnseed*lnirrg	0.58712936E-01	0.21247936E-01	0.27632301E+00
lnlabour*lnfertilizer	0.86563909E-02	0.44219065E-02	0.19577580E+01
lnlabour*lnirrg	0.18932378E-01	0.68537077E-01	0.27623540E+00
lnfertilizer*lnirrg	0.15525362E-02	0.10460145E-02	0.14836636E+01
Constant	0.12838193E+00	0.48413369E+00	0.26517868E+00
Age	0.39040979E-02	0.10068854E-01	0.38777976E+00
Years of farming exp	-0.18685676E-01	0.97314380E-02	-0.19202122E+01
Years of schooling	-0.17260814E-01	0.87444224E-02	-0.19740590E+01
Household size	0.27319441E-01	0.29957862E-01	0.91192894E+00
Distance to market	-0.13623369E+00	0.10790546E+00	-0.12625283E+01
Extension visit	-0.94212819E-01	0.30096423E-01	-0.31300262E+01
Years in cooperative	-0.24938160E-01	0.84762247E-02	-0.29423431E+01
Amount of credit	-0.28483782E-02	0.10128872E-01	-0.28121375E+00
Farm size	-0.25105091E-01	0.14684843E-01	-0.17095805E+00
Tenancy	-0.42855711E+00	0.38315234E+00	-0.11185050E+01
sigma-squared	0.14633567E+00	0.43452656E-01	0.33676671E+01
gamma	0.82493706E+00	0.91527256E-01	0.89667420E+01

log likelihood function = 0.55806010E+02

LR test of the one-sided error = 0.30441382E+02

Appendix 7: Irrigated System Stochastic Frontier Cost Function Results

the final mle estimates are :

Variables	coefficient	standard-error	t-ratio
Constant	0.53990429E+01	0.11215672E+01	0.48138381E+01
lnseed	0.48055430E-01	0.24317218E-01	0.19762231E+01
lnlabour	0.76665913E+00	0.10172559E+00	0.75358747E+01
lnfertilizer	0.59710274E+00	0.94843611E-01	0.62956559E+01
lnirrg	0.15991856E+00	0.33445078E-01	0.47815377E+01
lnseedsqr	0.52494784E+00	0.24346812E+00	0.21561248E+01
lnlaboursqr	0.37664613E+00	0.52121484E+00	0.72263123E+01
lnfertilizersqr	0.30106255E+00	0.11592200E+00	0.25971221E+01
lnirrgsqr	0.78061540E+00	0.45763123E+00	0.17057739E+01
lnseed*lnlabour	0.58703654E-01	0.36991218E-01	0.15869619E+01
lnseed*lnfertlizer	0.60965190E-01	0.17833039E-01	0.34186315E+01
lnseed*lnirrg	0.32073266E-01	0.17104039E-01	0.18751401E+01
lnlabour*lnlabour	0.95960791E+00	0.50101409E+00	0.19153321E+01
lnlabour*lnirrg	0.68498308E-01	0.14233105E-01	0.48126108E+01
lnfertilizer*lnirrg	0.36684194E-01	0.13259514E-01	0.27666319E+01
Constant	0.45709228E+00	0.67322082E+00	0.67896338E+00
Age	0.39885574E-02	0.17971877E-01	0.22193327E+00
Years of farming exp	-0.63305094E-01	0.21825917E-01	-0.29004616E+01
Years of schooling	0.96649180E-01	0.33092075E-01	0.29206599E+01
Household size	0.36226745E-01	0.30859434E-01	0.11739277E+01
Distance to market	0.23427761E+00	0.19361903E+00	0.12099912E+01
Extension contact	-0.60386107E-02	0.26360261E-02	-0.22905404E+01
Years in cooperative	-0.61926141E-02	0.30273930E-02	-0.20455457E+01
Amount of credit	0.21889006E-02	0.12810261E-02	0.17087088E+01
Farm size	-0.16069185E-01	0.53761324E-02	-0.29888433E+01
Tenancy	-0.11207840E+00	0.11007109E+00	-0.10182412E+01
sigma-squared	0.10370470E+00	0.37801308E-01	0.27434702E+01
gamma	0.79161525E+00	0.89453042E-01	0.80849483E+02

log likelihood function = 0.64164506E+02

LR test of the one-sided error = 0.37658204E+02

Appendix 8: Lowland System Stochastic Frontier Cost Function Results

the final mle estimates are :

Variable	coefficient	standard-error	t-ratio
Constant	0.37410242E+00	0.99905274E-01	0.37445713E+01
lnseed	0.15093082E+00	0.81119517E-01	0.18607670E+01
lnlabour	0.61338177E+00	0.31456788E+00	0.19499155E+01
lnfertilizer	0.68233739E+00	0.90266201E-01	0.75591681E+01
lnirrg	0.44264991E+00	0.35567956E+00	0.12445166E+01
lnssed sqr	0.77767860E+00	0.38939389E+00	0.19971578E+01
lnlabour sqr	0.28450591E+00	0.21980423E+00	0.12943614E+01
lnfertilizersqr	0.34098379E+00	0.14163904E+00	0.24074086E+01
lnirrg sqr	0.22194925E+00	0.20033498E+00	0.11078899E+01
lnseed*lnlabour	0.41889357E+00	0.23605479E+00	0.17745625E+01
lnseed*lnfertilizer	0.22437912E-01	0.23139323E-01	0.96968750E+00
lnseed*lnirrg	0.55267145E-01	0.16163612E+00	0.34192323E+00
lnlabour*lnfertilizer	0.12593154E-01	0.12443838E-01	0.10119825E+01
lnlabour*lnirrg	0.60818792E-01	0.77489389E-01	0.78486607E+00
lnfertilizer*lnirrg	0.14064416E-01	0.10555196E-01	0.13324680E+01
Constant	0.15215170E+00	0.62217542E+00	0.24454792E+00
Age	0.13248865E-01	0.82940618E-02	0.15973917E+01
Years of farming exp	-0.42378932E-01	0.11997968E-01	-0.35322469E+01
Years of schooling	0.17884364E-01	0.65084375E-02	0.27479580E+01
Household size	0.30048235E-01	0.19934012E-01	0.15073853E+01
Distance to market	0.12033313E+00	0.10532001E-01	0.11425503E+01
Extension visit	-0.20226013E-01	0.10983647E-01	-0.18414740E+01
Years of cooperative	-0.27281369E-01	0.15878860E-01	-0.17180761E+01
Amount of credit	-0.61145901E-01	0.39392925E-01	-0.15522051E+01
Farm size	-0.12107527E+00	0.55620592E-01	-0.21768066E+01
Tenancy	-0.36514858E+00	0.24489333E+00	-0.14910563E+01
sigma-squared	0.72158444E-01	0.16417190E-01	0.43952980E+01
gamma	0.85190875E+00	0.29233560E-01	0.29145438E+02

log likelihood function = 0.61342395E+02

LR test of the one-sided error = 0.48010099E+02

Appendix 9: SHAZAM code for the estimation of metefrontier and TGRs

```
* parm.txt contains estimated parameters of system-based frontiers
* KDN.txt contains 93 data observations for system 1
* KNO.txt contains 96 data observations for system 2
* NGE.txt contains 89 data observations for system 3
* READ ESTIMATED PARAMETERS OF SYSTEM-BASED FRONTIERS
read (parm.txt) parm / rows = 14 cols = 3
do # = 1,3
dim b# 14
copy parm b# / fcols=#;# tcols = 1;1
endo
* READ DATA (and construct matrices and vectors)
smpl 1 278
read (KDN.txt) system t ly lx1-lx4 lx11-lx14 lx22-lx24 lx33-lx34 lx44
smpl 94 189
read (KNO.txt) system t ly lx1-lx4 lx11-lx14 lx22-lx24 lx33-lx34 lx44
smpl 190 278
read (NGE.txt) system t ly lx1-lx4 lx11-lx14 lx22-lx24 lx33-lx34 lx44
smpl 1 278
gen one = 1
MATRIX x = one|lx1|lx2|lx3|lx4|lx11|lx12|lx13|lx14|lx22|lx23|lx24|lx33|lx34|lx44
stat x / means = xbar
dim x1 93 14 x2 96 14 x3 89 14
copy x x1 / frows=1;93 trows=1;93
copy x x2 / frows=94;189 trows=1;96
copy x x3 / frows=190;278 trows=1;89
do # = 1,3
matrix yhat# = x#*b#
endo
* OBTAIN AND PRINT PARAMETERS OF THE METAFRONTIER
matrix c = ((-xbar')|xbar')'
matrix A = (-x)|x
matrix b = -(yhat1'|yhat2'|yhat3')'
lp c A b / iter = 5000 primal = bstar
dim beta1 14 beta2 14
copy bstar beta1 / frows=1;14 trows=1;14
copy bstar beta2 / frows=15;28 trows=1;21
matrix beta = beta1-beta2
print beta
* OBTAIN AND PRINT TECHNOLOGY GAP RATIOS
do # = 1,3
matrix xbeta# = x#*beta
matrix tgr# = exp(yhat#)/exp(xbeta#)
stat tgr#
endo
matrix tgr = (tgr1'|tgr2'|tgr3')'
```

```
print tgr
stop
```